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MOTOR FUELS.*

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INTRODUCTION.

ONE of the important factors in our present system of transportation is the use of vehicles propelled by internal combustion motors. The use of automobiles and motor trucks has developed to such a stage that they may be regarded as practically indispensable and people in general are looking forward to wider use of this type of mobile equipment rather than anything in the line of restriction. The fuel upon which these motors are dependent is, however, one that is obtained from a raw material which is drawn from comparatively limited natural resources.

The term "motor fuel" is a broad one designed to include a wide range of products capable of furnishing power in internal combustion engines. At the present time, however, "motor fuel" actually means gasoline, a product principally derived from crude petroleum. The production of crude oil has increased steadily throughout the period of years during which the automotive industry has been developed, but the rate of increase has been relatively small. The production of gasoline has increased much more rapidly than the production of crude oil, but even this has not been comparable with the growth of the use of motor-

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propelled vehicles. Consequently a real problem exists in the matter of conservation of petroleum-derived motor fuel and the Bureau of Mines is endeavoring to promote measures favorable to more efficient production and is also working indirectly toward the development of satisfactory substitutes to be used in place of the present types of gasoline.

The present paper does not attempt to furnish an adequate discussion of this problem nor is it devoted particularly to desirable measures in the direction of conservation. The object has been to provide information of general interest concerning the present motor fuel situation with the hope that sufficient interest will be aroused to aid in supporting measures necessary for the more efficient utilization of one of the nation's most important resources.[1]

SCOPE OF THE PRESENT PAPER.

The material included in the present paper has been divided under four general heads which are treated in the order stated.

First, information regarding the production and use of gasoline.

Second, information regarding the marketing of gasoline.

Third, information regarding the physical and chemical properties of gasoline and the quality of the products marketed in the calendar years 1917 and 1919.

Fourth, information regarding present tendencies in the development of substitutes for gasoline.

PRODUCTION AND USE OF GASOLINE.

Before discussing the production of gasoline it seems necessary to attempt some sort of a definition. This is not an easy task and the following statement, taken from the 1916 Webster Dictionary, is hardly adequate for present purposes: "Gasoline; a volatile, inflammable liquid used as a solvent for oils, fats, etc., as a carburetant and to produce heat and motive power." The author is venturing the following definition as covering the present understanding of the word: "Gasoline is an inflammable, relatively volatile liquid, derived from crude petroleum or similar in

[1] The material included in the present paper has in large part been taken from the manuscript of a bulletin by H. H. Hill and E. W. Dean which is to be printed at an early date.

properties to petroleum derivatives, and containing a sufficient proportion of low-boiling constituents to permit the starting of an internal combustion motor under moderately unfavorable conditions."

The principal reason for venturing this definition is to permit the making of a distinction between the words "gasoline" and "naphtha." Naphtha is a petroleum product that is generally, though not invariably, less volatile than gasoline but which is chiefly distinguished by a lower content of low-boiling fractions. In other words, naphtha is gasoline minus the major portion of fractions distilling below the boiling point of water.

METHODS BY WHICH GASOLINE IS PRODUCED.

"Straight Refinery" Process.

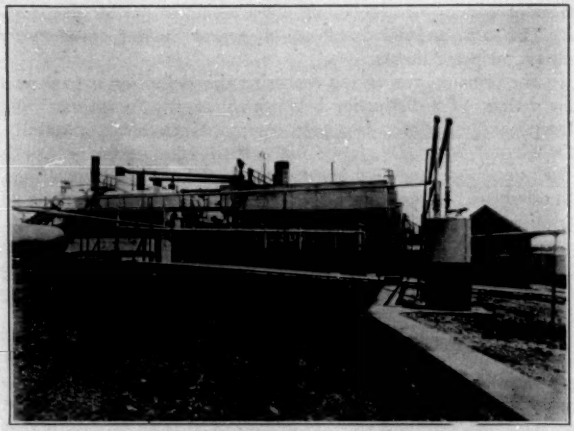
The oldest, and even at present the most important, method of producing gasoline is one involving distillation from crude petroleum. This method is frequently called the "straight refinery" process and gasoline produced by it is termed "straight refinery" or "straight run" gasoline. The basic process is that of fractional distillation, which involves separation of products having different ranges of boiling points. The process, as conducted in commercial practice, varies in a great many details and a discussion of these variations is beyond the scope of the present paper. The following brief description covers perhaps the most common general procedure:

Crude oil is distilled in cylindrical, horizontal stills which are heated either by coal or oil. The vapors pass through condensers and the liquid products are run into receiving tanks. Figure 1 shows a battery of crude stills with condensers and receiving tanks.[2]

The products separated from the crude oil by this primary distillation is in the refinery generally called "crude naphtha" or "crude benzine." The next process of treatment is usually a chemical one which is principally intended to improve the color and odor of the product. Crude naphtha is pumped into lead-lined agitators and is there treated, first with sulphuric acid, then with caustic soda solution, and finally with water. The stirring is

[2] The type of still represented in this illustration lacks the fractionating column employed in some of the more recent installations.

FIG. 1.



Southern Oil Corporation, Yale, Oklahoma. Crude oil stills, condensers and receiving tanks.

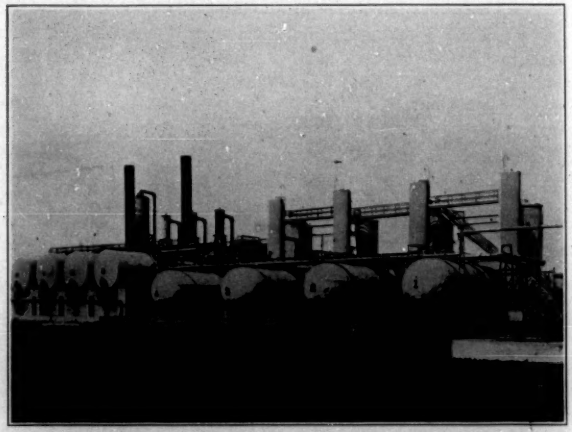
FIG. 2.

Southern Oil Corporation, Yale, Oklahoma. Agitators for chemical treatment of gasoline.

usually accomplished by blowing air in at the bottom of the agitator tank. Figure 2 shows three agitator tanks of this type.[3]

The final process in the refining of gasoline is a redistillation of the chemically treated crude naphtha. This distillation is generally carried out in so-called steam stills. Steam stills sometimes are heated entirely by closed steam coils, sometimes partly by fire while live steam is blown through the hot liquid. Steam stills

FIG. 3.



Cosden and Company, Tulsa, Oklahoma. Steam stills for redistillation of gasoline.

are generally, though not invariably, equipped with fractionating towers and are often operated in batteries which permit continuous rather than "batch" distillation. Figure 3 shows in the foreground steam stills of the type in which heat is supplied by closed steam coils. It will be observed that these stills are equipped with large fractionating columns.

The properties of the gasoline produced by the straight refinery

[3] Another type less commonly used involves the so-called continuous process in which crude naphtha passes through tanks containing respectively acid, water, alkali, and water. The continuous method has some advantages but according to the writer's observation is less extensively employed than the non-continuous type involving stirring by means of air.

process are subject to considerable variation and are controlled in part by the physical and chemical nature of the crude oil from which it is derived and in part by the procedure employed in the refinery. Straight refinery gasoline is composed chiefly of so-called saturated hydrocarbons, that is, hydrocarbons which are not chemically active. Most of the chemically active products which may be present in the crude naphtha from the primary

FIG. 4.

Carter Oil Company, Sistersville, West Virginia. Casinghead gasoline compression plant.

distillation are removed by chemical treatment with sulphuric acid. The property chiefly controlled by the refining process is the "end point" or upper boiling limit of the gasoline, which is fixed so as to separate the more volatile fractions from those generally marketed as kerosene or lamp oil.

"Casing-head" Gasoline Process.

A considerable proportion of the present supply of motor gasoline is derived not from crude petroleum but from natural gas. Gasoline from this source is commonly called "casing-head gasoline," due to the fact that before its commercial separation

was in vogue it was discovered as a condensate around the heads of well casings. Natural gas frequently contains appreciable quantities of liquid hydrocarbons which, although of relatively low-boiling point, can be readily separated. Two types of process to effect this separation are in general vogue, the older, and perhaps still the more important, being the so-called compression process. This process is usually operated according to the following general scheme: Natural gas is compressed under a moderate pressure and then cooled. Subsequently it passes through a second set of pumps which brings it up to a high pressure. Cooling after this second compression effects separation of the liquid hydrocarbons. This type of process is used only for natural gas of relatively high gasoline content. Figure 4 represents a plant operating the compression process. Most of the equipment is inclosed and cannot be observed, but the cooling coils appear in the foreground.

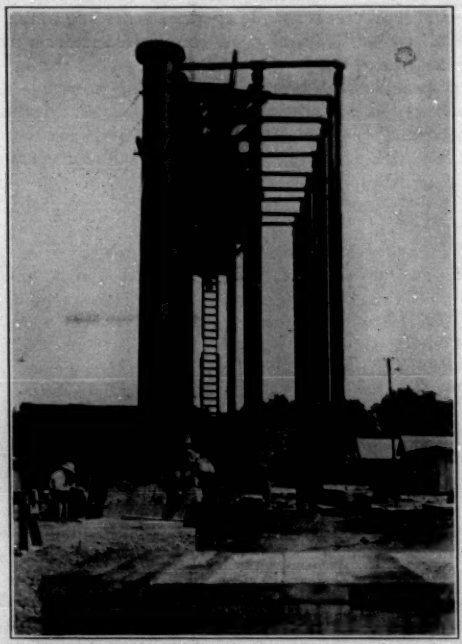
The other process is the absorption type which involves washing the natural gas with either a heavy naphtha or a high-boiling petroleum oil, thereby dissolving out the bulk of the liquid hydrocarbons. When naphtha is used as the absorbent a product is obtained from the absorption towers that is usually marketed without subsequent treatment. If a more efficient absorbent such as so-called straw oil or mineral seal oil is employed, the casing head gasoline must be separated by distillation. Figure 5 shows one of the first of the plants operating the absorption process.

Casing-head gasoline produced by the compression process is somewhat more volatile than that produced by the absorption process, but either product has too high a vapor pressure to permit safe handling or transportation.[4] The usual practice is to blend this gasoline either with naphtha or with high end point gasoline, after which it can be shipped and handled with a reasonable degree of safety. Casing-head gasoline blends were unfavorably regarded by users when first put on the market, but this was due more largely to improper methods of blending them than to any inherent bad qualities of the product. The blended casing-head gasoline now marketed is probably rather more satisfactory in use than the so-called straight refinery gasoline of equivalent average boiling point, this on account of its greater ease in starting

[4] The Interstate Commerce Commission has issued regulation specifying the maximum allowable vapor pressure for gasoline.

a cold motor. Statistics have shown that approximately 10 per cent. of the nation's supply of gasoline is of the casing-head variety and due to the necessity and desirability of blending with less volatile petroleum distillates it is probable that the proportion

FIG. 5.



Ohio Fuel Supply Company, Homer, Ohio. Casinghead gasoline absorption plant.

of marketed gasoline, containing products from natural gas, is several times this figure.

Cracking Processes.

Another recently developed method of producing gasoline is the so-called cracking process which has received a considerable

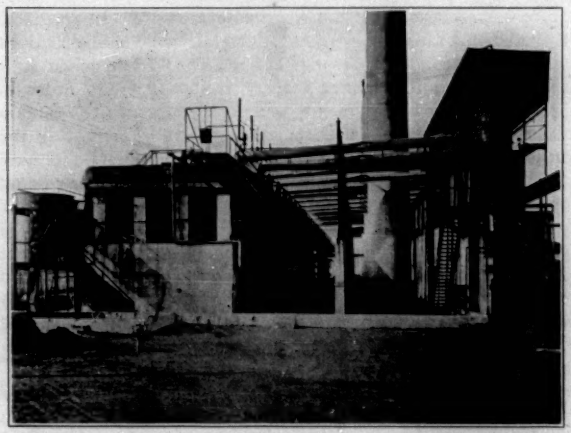
amount of publicity during the past few years. The basic principle of the cracking process is one with which all chemists are familiar, namely, that if organic compounds are heated at sufficiently high temperature they decompose with the formation of other compounds, a large percentage of which are of smaller molecular weight and lower boiling point. The cracking process has been used in the petroleum industry since the early days of its development, chiefly for the production of kerosene from the higher boiling fractions usually classed as fuel oil. This older process was conducted at atmospheric pressure. It appeared, however, that satisfactory yields of gasoline could not be obtained under these conditions as the hydrocarbons from which it is derived tended to vaporize before decomposing. In order to produce gasoline by the cracking process it is necessary to maintain the distillation system under pressure, thereby permitting the attainment of a high temperature before vaporization occurs. Cracking has also been effected by the scheme of passing liquid or vaporized oil through superheated tubes. Numerous types of gasoline-cracking processes have been developed, some of the pressure-distillation type, others of the tube type. At present the pressure-distillation type is the only one that has been developed on an important commercial scale. The process most commonly used is that of Burton, which was developed by the Standard Oil Company of Indiana and which is operated by this company and by various others, mostly of the Standard group.

Figures now available have indicated that approximately 10 per cent. of the nation's supply of motor fuel is derived from cracking processes. Cracked gasoline is similar to straight-run gasoline as regards physical properties, but there is an essential chemical difference due to the fact that the cracking reaction produces a considerable percentage of olefin or unsaturated hydrocarbons. The content of these hydrocarbons is commonly estimated by observing the percentage of the gasoline absorbed by ordinary concentrated sulphuric acid. This does not accurately measure the content of olefins, but for general purposes, however, the term "percentage of unsaturation," meaning percentage absorbed by sulphuric acid, is a convenient one to use. Untreated cracked distillates may have "percentages of unsaturation" as high as 40 per cent., a more usual figure, however, being 20 to 25 per cent. Cracked gasoline is usually marketed in the form of

mixtures with straight refinery and casing-head gasoline, these mixtures rarely being more than 12 per cent, unsaturated, which indicates that the products of the cracking reaction are blended with at least an equal amount of casing-head or straight-refinery gasoline.

Figure 6 shows a battery of Burton stills. These stills are distinguished from the more common types of refinery equipment

FIG. 6.



Standard Oil Company ot Kentucky, Louisville, Kentucky. Burton gasoline cracking stills.

by the fact that they are operated under pressure and that they are equipped with special types of fractionating towers.

STATISTICS REGARDING THE PRODUCTION AND USE OF GASOLINE.

Statistical information is frequently uninteresting and unless figures are carefully interpreted it may be misleading. As regards the production and use of gasoline, however, the information now available is so definite and impressive that misunderstanding is practically impossible. In the present connection it is interesting to present data regarding the magnitude of the nation's production and consumption of gasoline, the relation between production

of gasoline and production of crude oil, which is the principle raw material from which it is derived, and the relation between production of gasoline and the magnitude of the most important outlet of consumption, which is the automotive engine. It is also interesting to note certain seasonal factors which have to do with the production, consumption and storage of gasoline.

TABLE I.

Showing Increases in the Annual Production of Gasoline in the United States.

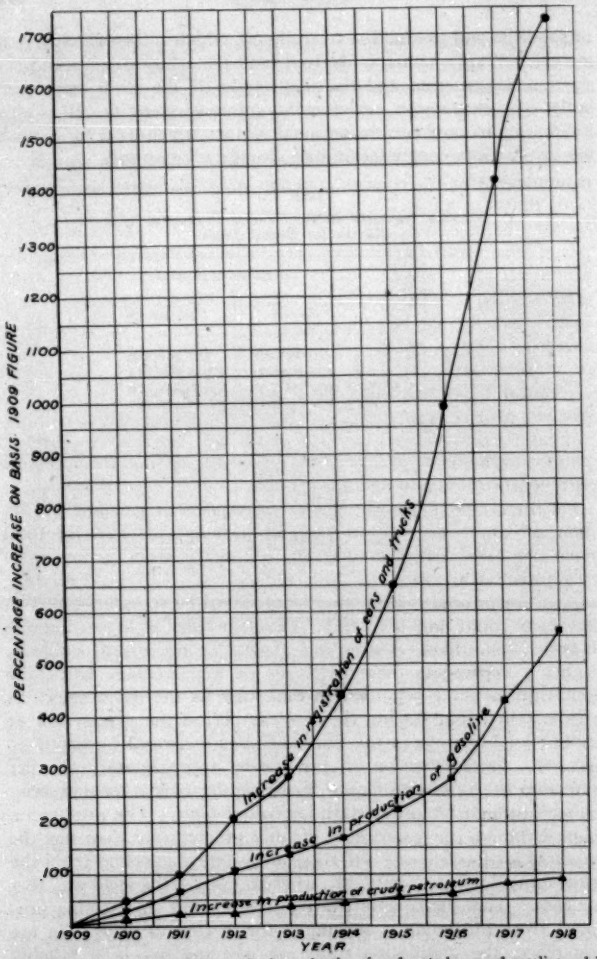
Year *	Production of gasoline	
	Barrels	Gallons
1909.....	12,900,000	541,800,000
1916.....	49,020,967	2,058,880,614
1917.....	67,870,153	2,850,546,426
1918.....	85,007,451	3,570,312,942

The increase in production of gasoline during the last few years is shown by the figures in Table I.

Assuming that the average refinery price of gasoline during the year 1918 was 18 cents per gallon, it appears that the total value of the year's production of motor fuel is approximately $650,000,000.

An interesting relation may be observed by comparing the increase in production of crude petroleum and gasoline and the increase in number of cars and trucks in use in the country. Figure 7 represents these increases on a percentage basis, the 1909 figures being regarded in each case as the basic ones. It will be noted that during the 10-year period the production of crude oil from wells in the United States increased by about 95 per cent., the production of gasoline by approximately 560 per cent. and the number of cars in service by over 1700 per cent. These figures bring out certain important facts. The production of gasoline has increased at a notably greater rate than has the production of crude oil. In 1909 the yield of gasoline from the crude refined was 10.7 per cent., whereas in 1919 the yield was 26.1 per cent. This increase in the relative amount of gasoline produced from the crude is accounted for in several ways. In the first place, the distillation range of gasoline has been notably

FIG. 7.



Showing relative increases since 1909 in the production of crude petroleum and gasoline and in the registration of motor cars and trucks.

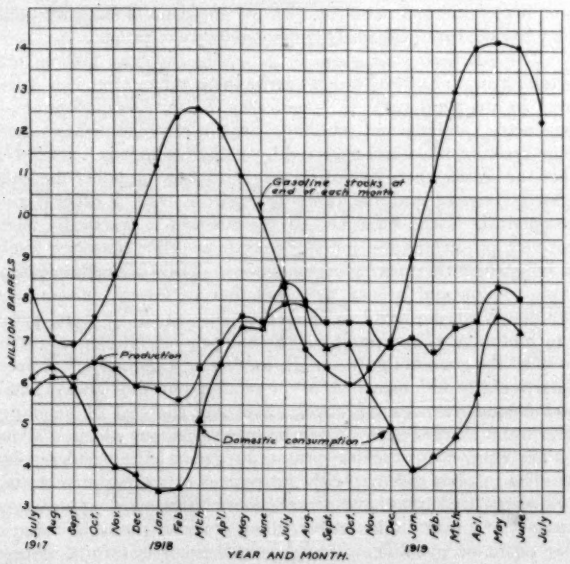
changed, products now on the market being of considerably higher average boiling point than those in 1909. The production of casing-head gasoline and the use of cracking processes have been important factors in increasing the apparent yield of gasoline from crude oil. In addition there undoubtedly have been increases in the efficiency of the conventional types of refinery equipment such as crude stills and steam stills. It may be noted, also, that the average quality of the crude oil produced in the country has probably improved as regards gasoline content. It is a question as to how near the present percentage of gasoline production per unit quantity of crude oil approaches the maximum that is commercially practical. It is impossible to make predictions regarding the future quality of crude oil. As regards efficiency of refinery equipment, it has been estimated that this may be improved on the average by a maximum not over 10 per cent. The production of casing-head gasoline undoubtedly has not reached a maximum but here again it is difficult to attempt an estimate. The use of cracking processes certainly has not developed to the maximum possible extent and the author has in the past ventured to predict that the quantity of gasoline produced from the crude could, if desired, be practically doubled if maximum use were made of this means of production. These estimates have not been strenuously contradicted but the author is frank to admit that his own optimism has decreased considerably since they were offered. It is still believed that the use of cracking processes could double the production of gasoline, but it appears that this is not likely ever to be accomplished as there is a marked tendency for increases in the use of fuel oil, which is the product that must necessarily be sacrificed in case maximum production of gasoline is attained through cracking. It is now believed that the chief limiting factor for the use of cracking processes is likely to be the demand for fuel oil. As regards further increases in the end point of gasoline, considerable doubt exists. Many authorities in the automotive industry claim that the present limits are too high, although this probably means that they are too high for the types of engines that can and will be developed in the reasonably near future. The present considerable demand for kerosene indicates, moreover, that further changes in the quality of gasoline are not likely to occur in the immediate future as raising the end point of gasoline inevitably decreases the production of kerosene.

The fact that the number of cars in service has increased approximately three times as much as the production of gasoline is a fact meriting serious consideration. Although exact data on this point are not available, it is not believed that the average consumption of gasoline per car has notably decreased. The obvious inference is that in 1909 the percentage of gasoline used by automotive vehicles was considerably smaller than the percentage so used in 1918. Inasmuch as the use of gasoline and naphtha for other purposes than internal combustion engines is increasing rather than decreasing, it is entirely reasonable to believe that at no very distant time the demand for gasoline is likely to exceed the supply unless the producers of gasoline add to their already considerable accomplishments in production, or unless the fuel efficiency of automotive equipment is considerably improved. It is realized that the production of gasoline during the present calendar year (1919) has been slightly in excess of consumption, but this is readily accounted for by the fact that the petroleum industry increased its volume of production during the war, whereas the manufacturers of automobiles and trucks have not yet gotten back to pre-war operating efficiency.

Aside from statistical evidence indicating the necessity of conservation, it is interesting to observe certain facts regarding the seasonal variations in production, consumption and storage of gasoline. Figure 8 is of interest, although it may be noted that the facts most clearly brought out are not those indicative of normal tendencies. As regards the production of gasoline it may be observed that there is a slight seasonal fluctuation, refineries working at greater efficiency during the summer than during the winter months. The consumption of gasoline varies notably, due to the fact that automobiles and trucks are less extensively used in cold than in warm weather. The quantities of gasoline stored naturally vary in the opposite direction, the stocks at the refineries increasing during the winter months and decreasing during the warm weather. The curves in Figure 8 illustrate the general tendencies, although there are certain fluctuations in the maxima and minima which were caused by war-time conditions. It is of particular interest to note that stocks of gasoline reached an abnormally low mark during the late summer and early fall of 1918, there being at this time less than one month's supply of gasoline in reserve. This condition was what caused the regula-

tion prohibiting the use of motor vehicles on Sundays during a period of several weeks. It may be observed that although the consumption of gasoline in September, 1918, was less than that of August, which is normal, the consumption in September was also less than that in October, which is unusual. As regards

FIG. 8.



Showing stocks, refinery production, and domestic consumption of gasoline for the period, July, 1917, to July, 1919, inclusive.

the curve indicating quantities of gasoline in storage, it is interesting to observe an unusual situation for the present year. Maximum stocks of gasoline are usually in storage in the early spring, which was the case in 1918. In 1919 a maximum was not reached until May and no important decrease in stocks occurred until July. In July of 1917 and July of 1918 stocks were at a considerably lower level than in July, 1919.

MARKETING OF GASOLINE.

The marketing of gasoline is a subject that is of particular interest but does not, however, permit satisfactory discussion by a chemist. The following observations are presented with a certain degree of qualification. The author feels that the basic data are reliable but does not guarantee his interpretation in all cases. Gasoline marketing practice obviously is not controlled by any simple physical and chemical laws and any general tendencies that may be noted are principally emphasized by exceptions.

The marketing of gasoline generally involves jobbing and retailing organizations which handle the product after it is delivered by the producer. In some cases the three organizations—producing, jobbing and retailing—are entirely distinct, in others they are controlled and operated by a single company. Likewise, there are cases where two of the organizations are under the same general control and the other is separate. As a general rule competition in the retail end of the business is practically unrestricted, producing and jobbing companies selling gasoline freely to independent competing organizations. There are certain exceptions to this and it may be noted that in several cities in the Middle West the retail price is the same as the jobbers' price, which eliminates any profit for the independent retailer who tries to meet the general figure for the locality. This is not, however, a particularly serious matter as the retailer's profit is always small and frequently does not cover losses and the cost of handling. The usual margin is two or three cents a gallon, which is about 10 per cent. of the selling price. In general the small retailer handles gasoline chiefly for the purpose of attracting or retaining customers who purchase other commodities yielding a larger margin of profit. The larger filling stations probably make a fair profit on gasoline, although even here it is safe to assume that the really profitable branch of business is the sale of lubricating oil and occasionally other automobile accessories. It may also be mentioned that the system of retail distribution of gasoline is very highly organized and that customers receive service which is claimed to be the best maintained in any line of business. The author is frank to admit that with the possible exception of tobacco he does not know of any commodity which is as generally available and efficiently dispensed as gasoline.

As regards the price of gasoline, there are no general rules

which can be stated without bringing to mind a host of exceptions. The one generally recognized fact is that the jobber's price for gasoline is generally that fixed by the larger marketing organizations. What actually determines the prices selected by these organizations is something which can be determined only in a very general way and the chief point of importance to the general consumer is that competing organizations generally favor an upward rather than a downward revision.

TABLE II.

Showing Retail Prices of Gasoline in April, 1919, in Several Cities Throughout the Country.

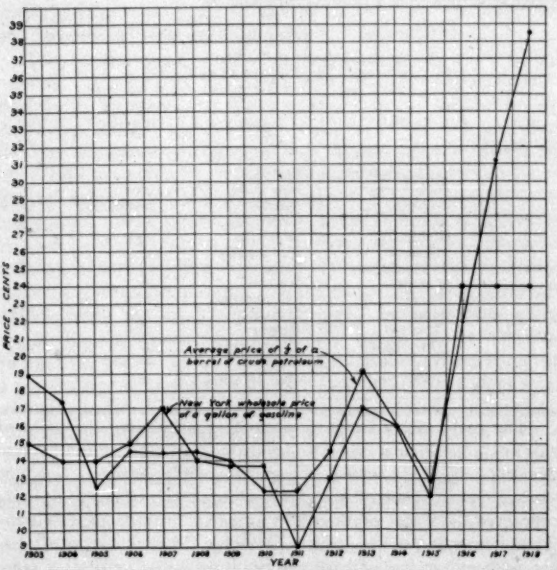
State	City	Retail price (cents per gallon)
Massachusetts	Boston	27.5
New York	New York	27.0
Georgia	Atlanta	26.5
Illinois	Chicago	23.0
Kentucky	Louisville	25.5
Alabama	Birmingham	26.5
North Dakota	Fargo	27.1
Kansas	Wichita	22.7
Texas	San Antonio	24.5
Montana	Missoula	29.0
Colorado	Denver	28.0
New Mexico	Albuquerque	32.0
Washington	Seattle	21.5
California	San Francisco	20.5

The most important general factors regulating the price of gasoline are the costs of transportation from refining centres and the demands of customers as regards volatility range. Gasoline marketed at a considerable distance from centres of supply is more expensive than that marketed in adjacent districts provided the grade demanded is the same. Likewise, districts that are satisfied with motor fuel of high end point generally get it at a more favorable price than similarly located districts that favor a more volatile type of gasoline. Figures in Table II show the retail prices maintained in the spring of 1919 in several cities throughout the country. It will be noted that prices were lowest in the Pacific coast states and in the Mid-Continent states nearest the producing centres, and highest in the Atlantic coast and Rocky Mountain states.

The most important thing to note in regard to the price of

gasoline is its relation to the price of crude oil. Figure 9 illustrates this in a decidedly satisfactory manner. On this diagram are plotted New York jobbers' prices per gallon of motor gasoline and the average prices throughout the country of a fifth of a barrel of crude petroleum. It will be observed that the curves are in general parallel with the single notable exception for the

FIG. 9.



Showing the relation between the price of crude petroleum and the price of gasoline.

year 1911, an explanation for which has not been worked out by the Bureau of Mines, although it seems possible that it may have been due to the fact that the Standard Oil Company was ordered dissolved by Federal injunction at about this time. It may be noted also that since 1916 the price of gasoline has held practically constant, whereas the price of crude petroleum has increased very considerably. This discrepancy is in part due to

the fact that the New York price has held constant, whereas in general throughout the country there has been an increase of 2 to 4 cents per gallon. Even with this increase, however, there would be a tendency for the gasoline and crude oil curves to diverge. A probable explanation of this is the fact that an increased demand for other refinery products has permitted the charging of a lower percentage of operating costs against gasoline than was customary in the earlier period. During the past year the supply of gasoline has slightly exceeded the demand, which is another reason for relatively slight increase in cost. In any event, the important fact is that the price of gasoline has been in general proportional to the cost of the raw material from which it is derived; which indicates that the oil refining industry at least has not been guilty of profiteering.

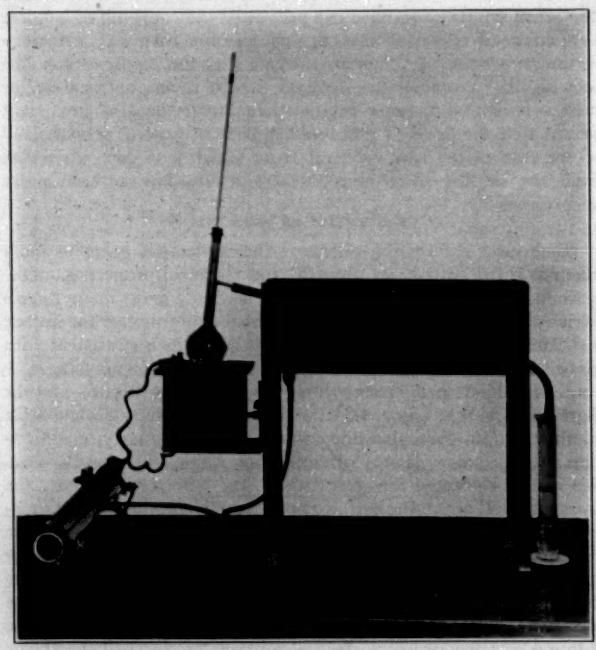
PROPERTIES OF GASOLINE.

The most interesting phase of the subject of gasoline for a chemist is, of course, its physical and chemical properties. Discussion of these, however, is likely to lead to a great many details which are not of general interest and realizing this fact the author has attempted to avoid technical details as far as is consistent with giving a reasonably adequate idea of what gasoline actually is.

The various properties which are commonly studied may be listed as follows: color, odor, "doctor" test for decomposable sulphur bodies, corrosion and gum formation, gravity, unsaturation, acidity, and volatility or distillation range. Of these properties it may be stated that color, odor, the "doctor" test and the corrosion and gumming test are not of sufficient interest and practical importance to warrant discussion in the present paper. The gravity test is one which has been highly regarded in the past but which actually is of minor significance. The present paper undertakes to show why it is of slight use in determining the quality of gasoline. The unsaturation test is of interest because it shows whether or not a gasoline contains products of the cracking reaction. The acidity test is one which covers care in refining and which has been included in government specifications, although its practical value has not as yet been definitely determined. The most important property of gasoline is its volatility, which is indicated by determination of its distillation range. The behavior of gasoline in an internal combustion engine is very largely determined by this property of volatility, which is the basic

one on which gasolines are graded by intelligent refiners. The older system of grading on the basis of gravity still holds to a limited extent but even this is based on the assumption that dis-

FIG. 10.



Apparatus for the analytical distillation of gasoline.

tillation range is a function of gravity, which assumption is correct only when considerably qualified.

VOLATILITY OR DISTILLATION RANGE.

The method for determining volatility involves an analytical distillation under regulated conditions. These conditions and

the nature of the apparatus used have a considerable influence over results and it is, therefore, necessary that tests be made in the same way if figures are to be regarded as comparable. Testing methods were in the past subject to considerable discrepancy, but since the recent recommendation of a certain method by the Bureau there has been a marked improvement in this particular. Practically all specifications are now based on a distillation by the method recommended by the Bureau of Mines, which has been described in various publications.[5] The apparatus used in the test is represented in Fig. 10 and consists essentially of a source of heat, a 100 c.c. distillation flash of specified dimensions, an ice-cooled condenser of specified dimensions, and a 100 c.c. graduate. The method involves heating the gasoline at a specified rate and reading temperatures when the first drop falls from the end of the condenser, when each of the respective 10 per cent. marks is reached, and when the dry point is reached, the latter being taken as the highest temperature obtainable shortly after the flask has apparently boiled dry at the end of the distillation. Of these various readings, the following are usually sufficient to define the distillation range of gasoline; first drop temperature, 20 per cent., 50 per cent., 90 per cent. marks and the dry point. These are the points usually employed in specifications. Figure 11 shows a curve plotted on the limits of the points set by the present government specification for gasoline. It will be observed that each of the ends of the curve is rather definitely fixed by the use of two points. A point for the 50 per cent. mark fixes the intermediate portion of the curve. This, however, is not absolutely necessary as there are inconsiderable possibilities of variation in this point when the end limits are specified.

In discussing the properties of gasoline a figure is sometimes employed which is called the average boiling point. This has not been employed in specifications as yet, but is of some value in providing a single figure to be used as an index in stating the volatility of gasoline. This figure is obtained by adding the first drop temperature, each of the 10 per cent. marks, and the dry point, and

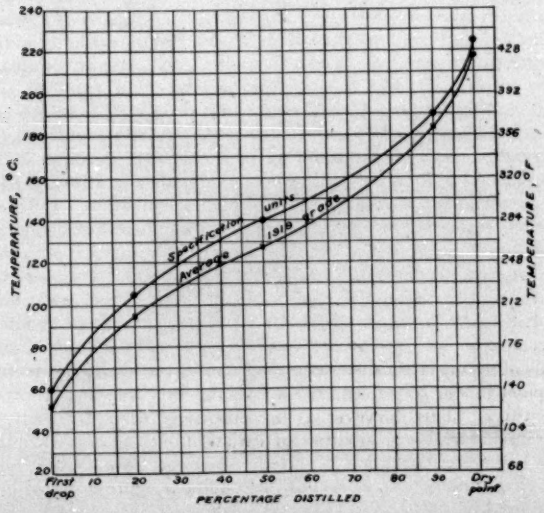
[5] American Society for Testing Materials, Year Book for 1915, pp. 568–569; or Part 1, Committee Reports 1916, vol. 16, pp. 518–521. Dean E. W., "Motor Gasoline, Properties, Laboratory Methods of Testing and Practical Specification." Bureau of Mines Technical Paper No. 214, 1919, 33 pages. Also Technical Paper No. 166 by the same author and with the same title, 1917, 27 pages.

dividing by eleven. This figure provides the same sort of information that would be obtained by means of a gravity test if the gravity test indicated what it is supposed by many to do.

DISTILLATION RANGE OF COMMERCIAL GASOLINE.

Three methods of producing gasoline have been discussed, namely, the straight refinery method, the casing-head gas method,

FIG. 11.

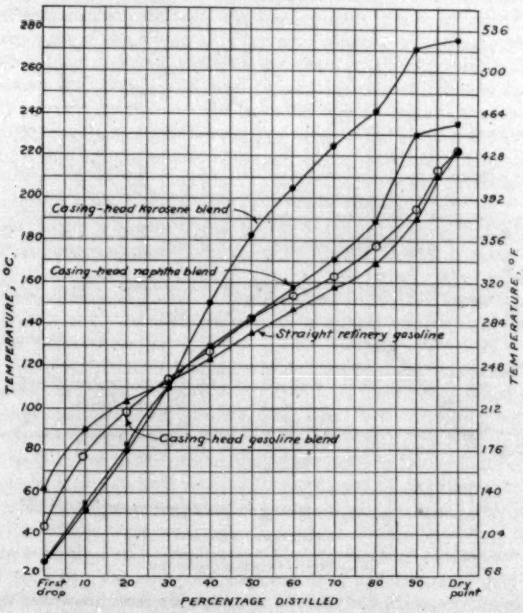


Showing curves representing the distillation limits set by the 1919 Government specification for motor gasoline and the average distillation range of the series of samples collected by the Bureau of Mines in April and May, 1919.

and the cracking method. Gasoline produced by the cracking process has no characteristic properties as regards distillation range. It is, however, frequently possible to distinguish gasoline blended with casing-head products from the straight refinery types. Figure 12 shows an interesting series of curves. One of the samples represented is a product made by blending casing-head gasoline with kerosene. Its distillation range is distinct from

that of any of the other samples. This type of fuel is not regarded as entirely satisfactory. It may be noted, however, that neither the gravity test nor the average volatility figures would distinguish this gasoline from one of the more desirable types. The

FIG. 12.

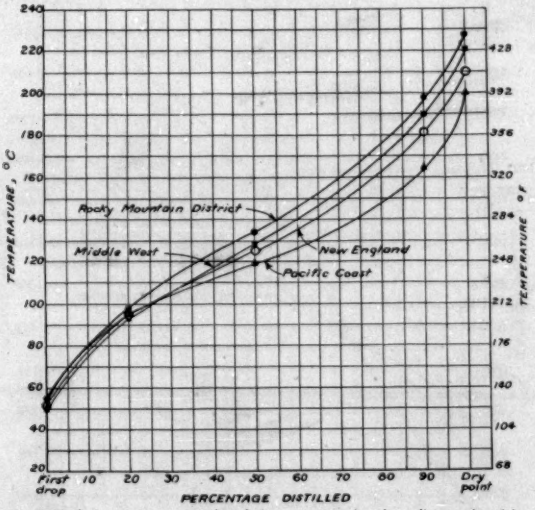


Showing distillation curves of three types of blended casinghead gasoline and straight refinery gasoline.

second sample of the series represented in Figure 12 is one composed of casing-head gasoline, blended with a so-called heavy or high-boiling naphtha. This type of product is notably superior to the kerosene blend but is not entirely ideal as motor fuel, although gasoline of this type is used in large amounts and with reasonable satisfaction. It is believed, however, that the prefer-

able type of casing-head blend is that represented by the third curve which shows the distillation range of a sample made by blending a very moderate quantity of casing-head gasoline with straight refinery gasoline. The curves for the three casing-head blends are shown in comparison with the curve for a straight refinery gasoline. It will be observed that the casing-head blends

FIG. 13.



Showing distillation curves representative of the average grades of gasoline marketed in 1919 in four general sections of the country.

have curves which for the first 20 or 30 per cent. are lower than the straight refinery product. Above this point the curves are higher than the curve for the straight refinery gasoline by varying amounts.

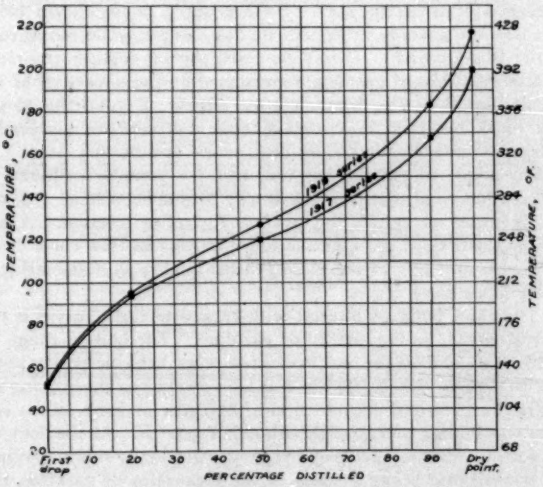
In the spring of 1919 and in the spring of 1917 the Bureau of Mines made surveys of the quality of gasoline sold throughout the United States. Certain of the results of these surveys are of general interest and are briefly discussed. In the first place, it was observed in the course of both surveys that the general quality

of gasoline varied to a certain degree in various sections of the country. The states on the Pacific coast received gasoline of relatively low-boiling range (or high volatility). The states on the Eastern coast were next as regards low-boiling range of gasoline. The Middle Western states received gasoline which was less volatile than that marketed on the Eastern coast, while the Rocky Mountain district received the least volatile grade of gasoline of any part of the country. Figure 13 shows four curves representing four different parts of the country, these curves being based on the average of figures for the samples collected in each of the four districts. It will be noted that as regards the more volatile fractions of gasoline, represented on the lower end of the distillation curve, the differences are slight. Beyond the 20 per cent. mark, however, the curves diverge and there are appreciable differences at both the 90 per cent. mark and the dry point. A similar series of curves was obtained for samples collected in 1917, although at that time the Rocky Mountain district was not homogeneous as regards the quality of gasoline received. A certain proportion of gasoline marketed in this district came from California and was of the same general quality as that marketed on the West coast.

The chief point of interest with regard to these curves is the general change in the quality of gasoline. The boiling range of gasoline has, during the past five or ten years, been increasing notably. In the days when gasoline was a by-product of the refining industry, incident to the production of kerosene or lamp oil, its end point was in the general neighborhood of 300° F. As the demand for gasoline increased, this end point has gradually raised. When the Bureau first began a study of the properties of gasoline, the figures usually maintained were between the limits of 350° F. and 400° F. The end point has continued to increase so that in 1919 the average was about 425° F. As regards the change in quality between 1917 and 1919, the curves in Figure 14 are instructive. These curves represent average figures for all of the samples collected in each of the respective surveys. It will be noted that the first drop and 20 per cent. temperatures are practically the same in both cases but that the curves diverge beyond this point, the difference at the 90 per cent. marks and dry points being between 15° C. and 16° C. This means that the gasoline marketed in 1919 was practically equal to that of 1917 as regards

starting qualities but that the properties controlled by the end point had changed somewhat. Improvements in engine design have undoubtedly made up for a considerable proportion of this difference and the gasoline marketed as present is probably used with fully as great satisfaction as that marketed in 1917. There is some question as to how much higher the end point can be raised

FIG. 14.



Showing average distillation curves for the series of samples of gasoline collected by the Bureau of Mines in surveys made in 1917 and 1919.

and still yield satisfactory results. This is a point concerning which detailed information is lacking. The Bureau believes, however, that in general the grades of gasoline now on the market are being used with a reasonable degree of satisfaction. The practice of the refining companies is to avoid, as far as possible, dissatisfaction on the part of their customers, and if a certain grade of gasoline is subject to too many complaints it is practically certain to be modified. It is realized, however, that the demands of users in different parts of the country are not the same and that

what is regarded as low-grade gasoline in one district would be looked upon as high-grade gasoline in another.

ACIDITY.

The test now recommended by the Bureau of Mines for determining acidity of gasoline is as follows: The residue left in the distilling flask after making a distillation is extracted with distilled water and tested with methyl orange indicator; reddening of the indicator shows that the gasoline contains acid which was present in the original sample, either free or in some sort of chemical combination. It has not been experimentally determined whether gasoline showing acidity according to this test has a particularly deleterious effect upon the metal parts of engines. It seems reasonable to suppose that it may have some undesirable effect, however, and inasmuch as this test is one which can be met by all refiners exercising reasonable care in preparing their products, it has been included in government specification. A study of the results of the Bureau's 1919 survey indicated that a majority of the samples were satisfactory according to this test.

UNSATURATION.

The test for unsaturation is one which the Bureau has never recommended in specifications as there is reason to believe that the types of unsaturated gasolines usually marketed are equal, if not superior in some ways, to the saturated types. The unsaturation test[6] is, however, interesting in showing the method by which gasoline was produced and is, therefore, worthy of brief discussion. The test employed by the Bureau simply involves agitating the gasoline with two volumes of ordinary concentrated sulphuric acid and noting what per cent. of the gasoline is dissolved. This test has been shown to cause a certain amount of polymerization of olefin or unsaturated hydrocarbons and on this account the percentage dissolved does not represent all of the olefines contained in the gasoline. As an empirical test, however, it has proven reasonably reliable and accordingly is of considerable value in the study of gasoline samples. The series of samples collected in 1917 varied in percentage of unsaturation from a fraction of one per cent. up to a maximum of six per cent. For

[6] Dean, E. W., and Hill, H. H., "Determination of Unsaturated Hydrocarbons in Gasoline"; Bureau of Mines Technical Paper No. 181, 1917, 25 pp.

the 1919 series the lower limit was the same but a common maximum was in the neighborhood of 12 per cent., showing that companies operating cracking processes have practically doubled the proportion of cracked gasoline turned out.

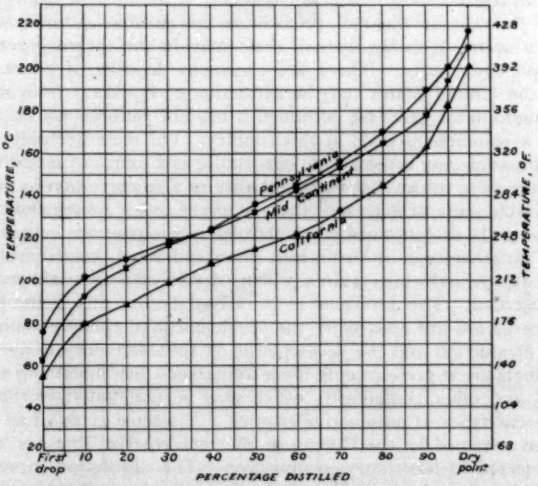
As regards the properties of cracked gasoline, a brief word may be in order. Cracked gasoline, even when carefully refined, has an odor which is more or less characteristic and which, to some at least, is slightly disagreeable. In addition, cracked gasoline is accused of the habit of polymerizing in shipment and storage with the depositation of gummy substances. Furthermore, cracked gasoline has been known to deposit gummy masses in the intake manifolds of engines and has also been accused of depositing carbon in cylinders. Some of these properties may be bad, although it is believed that in most cases the trouble is due to improperly refined cracked gasoline rather than to the simple presence of cracked constituents. In any event, however, some of the Bureau's experiments have indicated a notable point of superiority. When ordinary gasoline is used in a high compression motor there is likely to be a "knock" which is undesirable. Cracked gasoline has been found to be less subject to this tendency than is the more highly regarded straight refinery type. Frequent claims are made that cracked gasoline is superior to the straight run types when cars are run up steep grades or worked under heavy load, and the Bureau's experiments with the phenomenon of knocking have tended to substantiate these claims. In general, cracked gasoline is marketed in the form of blends which are not detected by the average user. It is believed, however, that even if the user were able to distinguish cracked gasoline, it would very likely be on account of its advantageous rather than its disadvantageous behavior.

GRAVITY.

Up to the last few years it was customary to rate gasoline on the basis of its Baumé gravity, and even to-day users are inclined to believe that a high Baumé gravity, which means a low specific gravity, is a desirable property. The gravity test under certain conditions does give indication of the distillation range of gasoline but in general furnishes highly unreliable information in this particular. It has already been pointed out that a mixture of kerosene and casing-head gasoline might have the same gravity

as a straight run gasoline. In addition it may be stated that the types of crude oil produced in different parts of the country have different physical and chemical properties and that for a given gravity there may be considerable difference in boiling range or *vice versa*. This fact is illustrated by the curves in Figure 15. The three samples represented have practically the same gravity,

FIG. 15.



Showing the distillation curves of gasoline of the same gravity obtained by the straight refinery process from Pennsylvania, Mid-Continent and California crude petroleum.

but have distillation ranges which are appreciably different. The uselessness of gravity figures in indicating quality of gasoline is further indicated by the fact that motor fuels now on the market may contain benzol and other coal tar derivatives which have abnormally low Baumé gravities.

GASOLINE SUBSTITUTES.

The subject of gasoline substitutes is one of particular interest, although definite information concerning it is decidedly limited. The first fact of importance to be recognized is that motor fuel is

essentially a source of energy and that the energy must come from somewhere. Wonderful statements regarding the discovery of new fuels appear periodically in the newspapers, these fuels generally being made by adding a small quantity of some secret compound to water. That these discoveries are one and all without particular value is proven by the fact that water is a substance which contains about as little free energy as anything one could select.

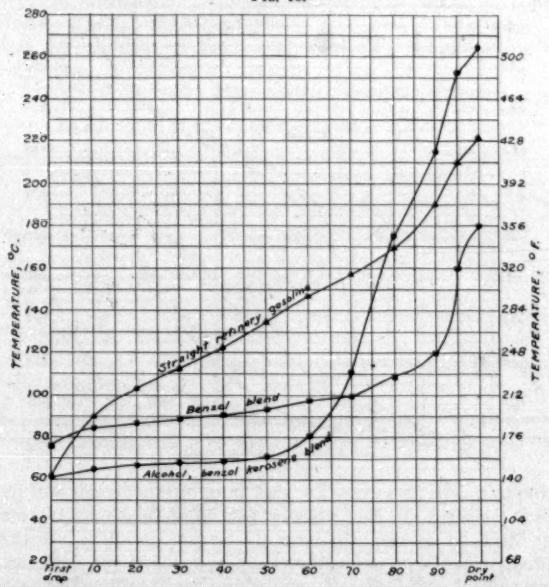
As regards the real possibilities of gasoline substitutes, it now seems probable that oil shale may in the future prove an important source. There are enormous deposits of oil shales in the United States and the extraction of liquid oil from these is undoubtedly feasible, although it has not yet been worked out on a commercial scale in this country. Oil shale probably will not assume any considerable importance as a source of motor fuel in the near future, but its potentiality as a resource gives a comfortable sense of assurance that the use of motor vehicles will not have to be discontinued when petroleum resources are exhausted.

Another type of fuel which offers unlimited possibilities for the future and which is already being developed to a certain degree is alcohol. The problems to be solved before this comes into general use are apparently the development of cheaper methods of production and the development of suitable types of engines. Efforts are at present being made to market a fuel containing alcohol and other components which may be used satisfactorily in present types of automotive engines. A sample of this fuel has been obtained by the Bureau in the retail market and has been subjected to laboratory examination. The distillation curve of this sample is shown in Figure 16. Its exact chemical composition was not determined but it was shown to contain both alcohol and benzol as well as a fair percentage of a product that might be classified either as a low-boiling kerosene or a high-boiling petroleum naphtha. The sample obtained by the Bureau was being sold at a price somewhat higher than that of motor gasoline. As regards its use, the Bureau has received reports from at least two reputable organizations, indicating that it was found at least as satisfactory as ordinary gasoline.

The type of gasoline substitute which is of most importance at the present time is the mixture of hydrocarbons obtained as a by-product in the coking of coal. These so-called coal tar distil-

lates, including benzol, toluol, xylol, etc., are hydrocarbons which are somewhat similar to the hydrocarbons found in petroleum, although of course there are well-recognized physical and chemical differences. During the war, coal tar distillates were largely used in the production of explosives and other munitions but since

FIG. 16.

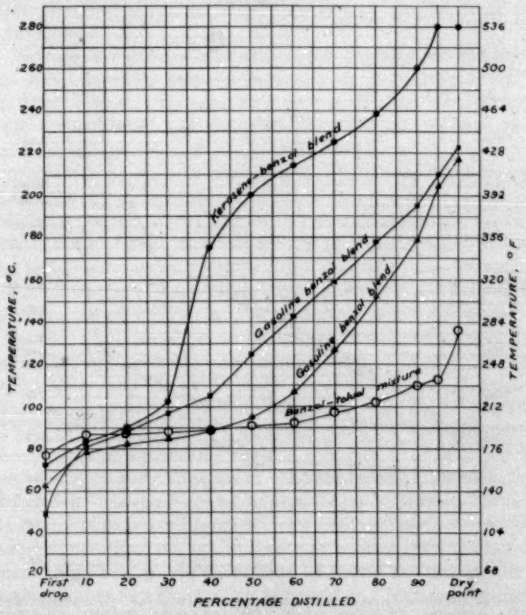


Showing distillation curves of three different types of motor fuel. (1) A blend of alcohol, benzol, and kerosene. (2) A blend containing benzol as principal constituent. (3) A straight refinery motor gasoline.

the termination of hostilities a considerable supply has been rendered available for motor fuel. Several companies have already undertaken to market benzol mixtures and in the course of its 1919 survey the Bureau secured a number of samples which were sold as gasoline substitutes containing benzol. The distillation curve of one of the samples is shown in Figure 16 and of some

of the other samples in Figure 17. The products are generally mixtures of coal tar distillates with petroleum naphtha. These products have been used under widely varying conditions and in some cases favorable results have been obtained, in others unfavorable results. Inquiries made by the Bureau have usually been

FIG. 17.



Showing distillation curves of four motor fuels containing coal-tar distillates.

answered by statements either that the substitutes were very satisfactory or very unsatisfactory, few of the users seeming to have found them about the same as petroleum gasoline.

The use of coal tar distillates as motor fuel does not, however, offer an ultimate solution of the motor fuel problem as the total production of these hydrocarbons is rather limited. In discussing

this subject in a paper prepared about two years ago the author had occasion to collect some statistics which are represented graphically in Fig. 18. This figure shows:

1. The nation's gasoline production in 1916.

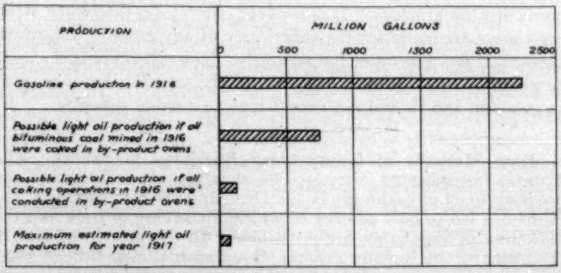
2. An estimate of the total light oil production if all the bituminous coal mined in the country were coked in by-product ovens.

3. An estimate of the production of light oil, if all coking ovens were of the by-product type.

4. An estimate of the actual light oil production for the year 1917.

The actual figure for hydrocarbons suitable for motor fuel is

FIG. 18.


PRODUCTION
MILLION GALLONS
0
500
1000
1500
2000
2500
Gasoline production in 1916
Possible light oil production if all bituminous coal mined in 1916 were coked in by-product ovens
Possible light oil production if all coking operations in 1916 were conducted in by-product ovens
Maximum estimated light oil production for year 1917

Showing the relative magnitude of petroleum gasoline production as compared with possible resources of coal tar distillates.

even less than that for total light oil produced, and it appears, therefore, that as a motor fuel resource, coal tar distillates are of relatively small importance. It may, for instance, be stated that since 1916 the production of gasoline has practically doubled while the quantity of coal mined has increased only about 17 per cent. The real importance of coal tar distillates as motor fuel occurs in districts adjacent to by-product coking operations where a reasonable proportion of the local gasoline supply may be filled by coal tar products.

Benzol and other coal tar distillates have certain disadvantages when compared with petroleum gasoline but have other very marked advantages; particularly in freedom from tendency to knock. An additional advantage lies in the fact that they have

a considerably higher calorific value per unit volume, and as this is the basis on which the user buys, he gets more for his money than he would from petroleum gasoline. It is believed that coal tar distillates, if properly used, are very satisfactory motor fuels and that there should be little difficulty in finding a market for the entire supply.

The Bureau's general feeling with regard to substitutes for gasoline is that they should receive all possible encouragement if produced and marketed in an intelligent and scientific manner. The nation certainly needs to increase its motor fuel resources and no step in this direction should be hindered. It should be recognized, however, that petroleum gasoline is a type of fuel for which present equipment has been designed and for which it is eminently satisfactory. It is believed, therefore, that when striking claims are made for the superiority of any gasoline substitute, these should not be taken too seriously. The substitute fuel should be given a fair trial but the user should be satisfied if it is as good as gasoline and should not expect it to be notably superior.

New Methods of Constructing Buildings in France. (*La Nature*, December 27, 1919.)—The shortage of workers and the pressing need of buildings in the Departments devastated by the Huns has led to new devices in which the saving of time and the reduction of hand labor are prominent. In the process of M. Ch. H. Besnard, an architect of the Government, elements of reinforced concrete are moulded in the factory under favorable conditions of temperature and humidity, where workmen are on the ground and not in mid-air, and where inspection and tests can be carried out with satisfaction. In erection a skeleton, consisting of (*a*) posts, carrying at the upper end very stout metal gutters, and (*b*) horizontal girders connecting the posts, is put up. The gutters, themselves, serve as lengthwise girders. From the peak of the roof descend the two sloping sides of glass or of tile, and both rest upon the inner edges of the gutters on the two sides of the structure. Outside of the actual elevation of the members and of their fixing in place, but little work need be done at the site of the structure. The roof has only three joints.

The same process is applied to dwelling houses as well as to factories, and in a characteristically French manner the esthetic features of the structures are cared for.

It is reported that a saving of more than 90 per cent. in the number of workers at the building itself is thus made—no inconsiderable matter in view of the 450,000 ruined buildings in France.

G. F. S.

A NEW NON-INTERMITTENT SENSITOMETER.*

BY

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THE first step in the testing of photographic plates, films, and papers by the sensitometric method involves the exposure of the material in some definite precisely determined manner. This is accomplished by use of an instrument known as a "sensitometer," which subjects various areas of the material to be examined to a series of exposures varying in value over the necessary range and in accordance with some definitely known predetermined ratio. Since the density of the developed areas over a considerable proportion of the scale of the material is directly proportional to the logarithm of the exposure, and, since it is usually desirable in producing a graphical representation of the characteristics of the material to plot density against the logarithm of the exposure, a series of exposures increasing according to some logarithmic function is usually chosen, thus producing an even distribution of determined points along the exposure axis. The exposure scales in most common use are those in which the exposures increase from step to step by consecutive powers of $2, \sqrt{2}$ or $\sqrt[3]{2}$, the particular scale used being that one which is best suited to the scale of the material being tested and to the requirements of precision necessary in the problem being considered.

The response of a photographic material to the stimulating exposure is a function not only of the intensity (I) of that stimulus, but also of the duration of time (T) through which the stimulus acts. Exposure, therefore, consists of two factors, time and intensity, and hence its value may be varied by a change in either the time or intensity factor. The desired variation in the time factor may be accomplished by either of two general methods, the continuous or intermittent. In case of the former the exposing radiation is allowed to act continuously from the instant of starting until the desired exposure has been obtained, while in the latter the exposure is broken up into a series of flashes varying

* Communicated by Dr. C. E. K. Mees. Communication No. 64 from the Research Laboratory of the Eastman Kodak Company.

in duration for the various areas being exposed. There are in general, therefore, three distinct ways in which a photographic plate may be exposed for sensitometric purposes, and sensitometers may conveniently be divided into three classes according to the way in which the required variation of exposure is obtained:

CLASS A: I variable, T constant (Intensity Scale Instrument).
CLASS B: I constant, T variable and continuous (Non-intermittent Time Scale Instruments).
CLASS C: I constant, T variable and intermittent (Intermittent Time Scale Instruments).

Sensitometers producing graded exposures in all three of the ways mentioned above have been used by various workers in the field of photographic research.

The chief examples of Class A are the tube sensitometers and tablet sensitometers. The former consist of a series of tubes or cells of equal lengths at one end of which is placed the photographic plate, the other ends of the various tubes being closed by opaque plates containing apertures of variable areas. If these apertures are properly illuminated, the intensity of the light acting on the photographic plate at the other end of the tubes will be proportional to the areas of the apertures. In order to obtain high precision with this type, extremely good machine work is necessary, and great care must be exercised in obtaining proper illumination of the apertures. Difficulty also arises in obtaining a long scale of exposures and at the same time placing the exposed areas close together on the plate, this being highly desirable in order to minimize as much as possible the errors arising from the inequalities of coating. Sensitometers of this type have been used by Spurge,[1] Vogel,[2] Luther[3] and others.

Tablet sensitometers are made by producing on a transparent support, such as glass or film, a series of deposits varying in density according to the desired scale of exposures. These densities may be produced by use of pigmented or neutral dyed gelatine or by a photographic deposit of silver grains developed in a non-staining developer. The plate to be tested is printed in contact with the tablet and the densities of the various tablet areas, having been previously measured, the intensity of the light acting on the various areas of exposed plate can be determined. The chief difficulties in the preparation of such tablets lie in the exact measurement of the various densities, in obtaining and reproduc-

ing precisely the densities desired and in obtaining media that are photographically non-selective in regard to spectral absorption. The best known examples of this type are the Warnerke [4] and Chapman-Jones [5] tablets.

Sensitometers of Class B have been but little used. One form proposed by Cowan [6] consists of a plate which is allowed to fall, under the action of gravity, between the light source and the material to be tested. In this plate is cut a series of slots of different lengths, allowing the light to act for various intervals of time upon the areas of sensitive surface behind the several slots. The chief objection to this type is the necessity of applying a correction to compensate for the variable velocity of fall due to gravitational acceleration. Another form proposed by General Sebert [7] is much more satisfactory but does not seem to have been used very extensively. This consists of a plate-holder, carrying the sensitive material to be exposed, driven at a constant velocity past a metal plate, in which are cut slots of different lengths. The constant velocity is obtained by means of a clock-work controlled by a pendulum.

Class C includes instruments of the sector wheel type. These consist of an opaque disk in which are cut slots of various angular dimensions, mounted on a shaft, and driven at a fairly high angular velocity. The material to be exposed is placed behind this rotating disk and various areas receive exposures which are directly proportional to the angular dimensions of the slots. This instrument has been very extensively used in photographic research and is the most common and best known form of sensitometer. This form was proposed as early as 1840 by Claudet, and again in 1889 by Bolton.[8]

Various workers have used instruments of this type differing slightly in detail; for instance, Hurter and Driffield [9] adopted one, employing a disk having nine steps, increasing in angular dimensions by consecutive powers of 2, thus giving exposures doubling in value from step to step. Scheiner [10] adopted a disk in which the ratio of adjacent slots was 1 : 1.27, thus giving the determined points very close together on the exposure axis and for a given number of steps covering a relatively small range of the scale of the material. An instrument of this type was constructed in this laboratory having a disk cut so as to give exposures, increased by consecutive powers of $\sqrt[3]{2}$ for use in the testing of

photographic printing papers which have a scale much less than that of plates, or for the very precise determination of a portion of a plate characteristic, the increased precision obtained being due to the fact that three times as many points are determined as with the instrument giving exposures increasing by powers of 2.

A very complete description of the sector wheel sensitometer and a discussion of the precision obtainable in the cutting of the disk has been published by Sheppard and Mees.[11]

The chief objection to the sector wheel instruments is due to the fact that a photographic surface does not in general integrate an intermittent exposure. The effect produced, generally referred to as the intermittency effect, has been investigated by Abney,[12] Vogel,[13] Schwarzschild,[14] Howe,[15] and others. Sheppard and Mees have found that under certain conditions, at least, this failure of the plate to integrate an intermittent exposure is not appreciable.

It has been considered by most workers in this field that such instruments, when operated with the speed of rotation of the disk between certain limits, would give at least correct relative values of speed for various materials and practically all speed determinations have in the past been made with this type of sensitometer.

In the course of the sensitometric work carried on in this laboratory, it was noticed that certain discrepancies between the relative speed values determined by these instruments and those measured by exposure in the camera were occurring. These were especially notable in the case of the relative values for materials differing widely in speed, such as, for instance, negative and positive emulsions. In the determination of the speed of the slow material with the sector wheel instrument it was found necessary to multiply the standard exposure time by some factor in order to obtain a number of points sufficient for the satisfactory determination of the shape and position of the characteristic curve. Then, in order to obtain the correct relative speed value, the speed read from the curve thus established was divided by the factor used in increasing the exposure time. It was also noted that speed values obtained by using increased times of exposure were not proportional to such increases of time, even on the same material.[16]

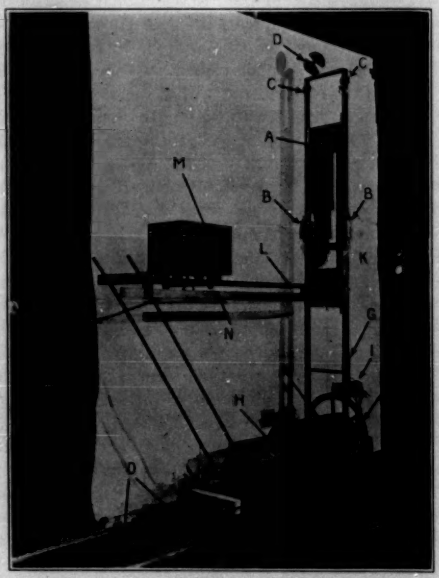
On account of the existence of the discrepancies mentioned above, it was decided to replace the rotating sector sensitometers, in which the exposure is intermittent, by new instruments of Class B, giving continuous exposures with the intensity constant and time variable. Several types were developed, and in the following pages only brief mention will be made of these and the larger part of the space devoted to a detailed description of the form finally adopted, together with data showing the difference between the performance of this and the intermittent machines.

The instruments to be described may be divided into two general types: (1) Those using a thin metal plate in which are cut slots of various lengths, those lengths being proportional to the exposures which it is desired to impress on the sensitive material. Such plates are then moved across the surface of the material to be exposed at a velocity which must be maintained at a precisely uniform value from the instant at which the exposure starts until it is terminated. (2) In this class of instruments the slotted shutter plate, moving at a uniform velocity, is replaced by a shutter plate which is caused to move in a discontinuous manner across the surface of the sensitive material. This motion is produced by the application of a series of impulses, each one of which causes the shutter plate to move a fixed distance at an extremely high velocity, the time intervals between the application of successive impulses being so adjusted that a series of exposures increasing by successive powers of either 2, $\sqrt{2}$ or $\sqrt[3]{2}$ as may be desired, is impressed upon the sensitive material. The distance through which the shutter is moved depends upon the size of the area required for measurement. The velocity of movement is made as high as possible in order that all points of a given area shall receive equal exposures. A consideration of the principles involved in these two types of instrument shows that in the case of the former type (1) the precision obtainable depends upon the accuracy with which the various slots in the shutter plate can be cut and upon the uniformity of the velocity with which that plate can be moved throughout the entire exposure period; while in the latter case, (2), the entire burden of securing precision is thrown upon the mechanism which determines the time intervals between the successive impulses applied to the shutter plate.

The first instrument constructed, Fig. 1, was of Type 1 (Class

B). An aluminum plate, *A*, 15 cm. wide by 60 cm. long, is mounted so as to move up and down between vertical ways. The weight of this plate is balanced by two counter poise weights, *B*, *B*, carried at the ends of silk cords attached to the upper end of the plate and running over small pulleys, *C*, *C*, located at the

FIG. 1.



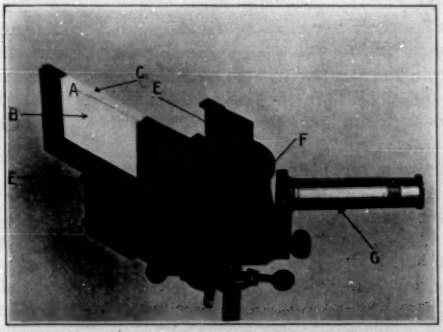
top of the ways, one on each side. The plate is moved up and down in the ways by means of a silk cord attached to the top and bottom of the plate and running over the grooved pulley wheels, *D* and *E*, of which the larger one, *E*, is the driving member, *D* being an idler. Power is applied to *E* through a train of gears, not shown in the photograph, connected with the shaft of the chronograph drum *F*. The train of gears is so arranged that by moving the lever, *G*, into the proper position, the plate may be made to move either up or down, and the gear ratios are so

adjusted that the linear velocity of the plate when moving down is sixteen times as great as when it is moving in the upward direction. A Leeds and Northrup constant speed-governed motor furnishes the power for operating the mechanism, and is connected to the shaft of the chronograph drum by means of a worm and worm-wheel. Four interchangeable worm-wheels are provided, having different numbers of teeth, so that angular velocities of 1, 2, 4 and 8 units may be imparted to the drum, thus making it possible to vary the exposure time over a considerable range. In order to eliminate the possibility of injury to the mechanism, due to the failure of the operator to shut off power, or to throw the lever, *G*, into its neutral position when the plate has reached the end of its travel, electric contacts are placed at the upper and lower ends of the ways so that when the plate reaches either of its extreme positions, a low voltage circuit is closed, which energizes the solenoid *I*, which in turn opens the 110-volt circuit supplying power to the driving motor *H*. The photographic plate to be exposed is carried in a plate holder, which slides into position behind the shutter plate at *K*. Two interchangeable shutter plates are provided, in one of which the length of the opening increases by powers of 2 and in the other by powers of $\sqrt{2}$. The nine steps are each 1 cm. wide and their lengths are precisely limited by means of adjustable steel edges attached to the aluminum plate by screws. In case of the very short steps the length is adjusted to the desired value by use of a micrometer microscope. In the face of the plate holder are two openings, each 1.5 cm. wide by 9 cm. long, and separated by a distance of 1 cm., each opening being provided with a dark slide. In using the shutter plate in which the openings vary by powers of $\sqrt{2}$, the dark slide covering the upper opening in the plate holder is withdrawn, while the shutter plate travels up. When the shutter plate has completed its upward motion this dark slide is pushed in and the one covering the lower opening is withdrawn, while the shutter plate moves down at sixteen times its upward velocity. In this way a sensitometer strip consisting of two nine-step portions is obtained, having seventeen steps with exposures increasing by powers of $\sqrt{2}$, there being one step on each, having equal exposures for the purpose of checking. In case the shutter plate having the steps increasing by powers of 2 is used, a series of nine exposures varying from 1 to 256 is obtained by allowing

the shutter plate to travel in one direction only, and as this range is sufficient for most cases, it is not necessary to make use of the double motion of the shutter. Both dark slides may therefore be withdrawn and the two strips exposed simultaneously.

In some instances it becomes necessary to measure the intensity of illumination acting on the photographic plate and to provide for such cases a photometric attachment is provided. A pair of ½-inch steel rods, *LL*, are mounted in a horizontal position, as shown. Moving on this track is a light tight box *M*, in which is mounted a small standard incandescent lamp. An aperture in

FIG. 2.



the end of the box permits the light from this lamp to fall upon the back of the plate holder *K*. Now, in order to measure the intensity of the illumination incident upon the plane occupied by the photographic plate during exposure, the plate holder is removed and in its place is inserted the special photometer head shown in Fig. 2. The photometer screen *A*, consisting of a block of magnesium carbonate the opposite surfaces, *C* and *D*, of which are carefully cleaned by scraping down with a steel straight edge so as to be of equal reflecting powers, is mounted so that when the attachment is in position the surface *C* lies in the plane occupied by the photographic plate when it is in position for exposure. Two mirrors, *EE*, a photometer cube, *F*, and eye-piece, *G*, constitute the essential parts of this attachment which is very similar to the ordinary Lummer-Brodhun photometer head. When this

is in position the surface *C* is illuminated by the light used for exposing the photographic plate while *B* is illuminated by light from the standard lamp in *M*, Fig. 1. A photometric match is made by running *M* back and forth on the track *LL*, and the distance of the lamp from *B* is read off on scale *N*, Fig. 1. The candle-power of the lamp being known, the illumination on *B*, Fig. 2, and hence on *C* can be computed. In case the intensity of the exposing light is extremely variable and it is desired to read the illumination on the photographic plate during exposure, the magnesium carbonate block *B* can be removed from its position and in its place can be inserted a holder containing the photographic plate to be exposed. The plane of the plate to be exposed occupies the same plane as surface *C*. In order that the two sides of the photometric screen shall be of equal reflecting power, a second photographic plate is placed so that its face occupies the plane of surface *B*. In such a case the room in which work is being done must be darkened and illuminated only by the proper safelight. By the use of such a photometric screen, the faces of which are composed of photographic plates, the intensity readings may be made while exposure is taking place. The entire sensitometer is mounted on a heavy metal base which can be moved to any desired position on the track *OO*. This instrument gave very satisfactory results, although considerable difficulty was experienced in obtaining a sufficiently uniform velocity of the shutter plate, and in keeping the various parts of the mechanism in good adjustment. These disadvantages, together with the fact that considerable skill and experience is required on the part of the operator, makes the instrument unsuitable for routine work.

In an effort to devise an instrument more completely automatic in action, requiring less attention on the part of the operator, and at the same time giving precisely timed exposures, attention was turned to the second type (2), of Class B, in which a series of separate impulses are applied to the shutter plate.

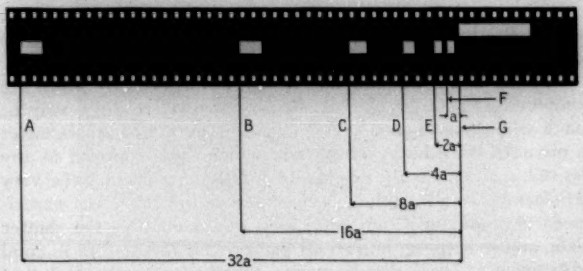
For the purpose of description such a sensitometer may be divided into two parts: (1) the timing device which closes the electric circuit at the proper instants of time, thus furnishing the desired series of impulses; and (2) the exposing machine, consisting of the light source of constant intensity which may be covered and uncovered at the proper instant by an impulse furnished by the timing device, a sliding shutter plate so constructed

as to be operable by a series of impulses from the timing device, a plate holder carrying the photographic plates to be exposed, a plate holder slide for holding the plates in position behind the sliding shutter, and the necessary control keys for starting and stopping the timing mechanism. The elements of the exposing machine are all mounted together, forming a complete unit which can be used in an undarkened room and at any desired position in the building irrespective of the location of the timing device.

THE TIMING MECHANISM.

As previously stated, the burden of obtaining precision in this type of sensitometer is thrown upon the mechanism which deter-

FIG. 3.

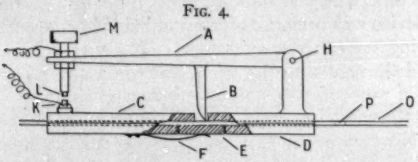


mines the time intervals between successive impulses. After careful consideration and preliminary trials, it was decided to adopt a perforated tape as a means of producing the correctly timed series of impulses. This tape is made by punching holes *A, B, C,* etc., spaced at the proper intervals, in a strip of motion-picture film as shown in Fig. 3. This film is then drawn through a contact maker at a constant linear velocity by means of a mechanism driven by a constant speed-governed motor. As each hole passes a certain point in the contact maker a contact is made which operates a relay which in turn energizes a solenoid, the plunger of which is so arranged as to move the shutter plate one step in the desired direction. In the first model the film itself was allowed to run directly between the two points of the contact maker, thus allowing them to come together only when one of the holes came

into position. This required that one of the points press continually on one surface of the film and it was found that this contact point soon became fouled, due to the collection of dust and particles of the film itself, so that the making of a good electrical contact was very uncertain. A contact maker, such as is shown in Fig. 4, was then devised, and has proven very satisfactory. The figure is a partial cross section showing the film *O* in position between the two metal plates *C* and *D*, which are separated by a distance equal to about twice the thickness of the film. This distance is necessary in order that a splice in the film may pass easily between the plates. The arm *A*, pivoted at one end on the point *H*, carries at the other end a screw *M*, with a platinum contact point *L*, at its lower extremity. The other contact point *K* is mounted on plate *C*, as shown.

At a distance from *H*, equal to one-sixth of the total length

Fig. 4.



of the arm *A*, is a steel lug *B* rigidly attached to *A* and projecting through an opening in plate *C*. The lower extremity of this lug rests upon the upper surface of the film *O*, and supports the arm *A* at such a height that *L* and *K* are separated by about 1 mm. When a hole in the film comes into position under lug *B* its edge moves down by the thickness of the film .2 mm., allowing *L* to move down by six times that distance, thus making a contact between *L* and *K* which completes the relay circuit. The hardened steel plate, highly polished on the upper surface, is fitted into an opening in plate *D*, as shown, and is pressed upward against the lower face of the film by the spring *F*, thus keeping the film pressed firmly against the lower face of plate *C* at all times.

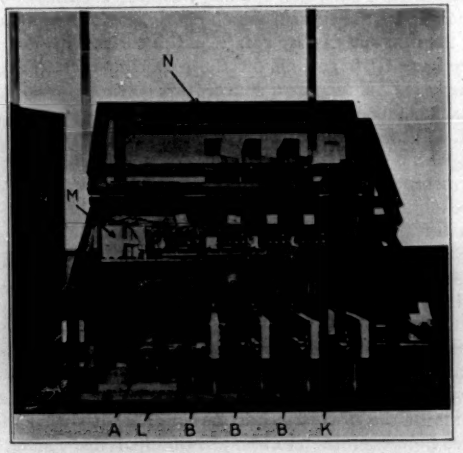
The film containing the perforation is pulled through this contact maker by means of a film sprocket, on the circumference of which are rows of teeth engaging the perforations along the edges of the film. This sprocket is driven at a constant angular velocity by means of a governed motor so that the number of perforations

passing a given point in a fixed time will be constant. Since a long strip of film may change its length slightly with age or with variation in conditions of temperature and humidity, the spacing of the operating openings (*A*, *B*, *C*, etc., Fig. 3) is determined in terms of the number of edge perforations rather than by actual linear measurement. This procedure eliminates any error of timing that might result from a linear expansion or contraction of the film due to any of the various causes of change of length. A special punching device is used for spacing the operation openings. This consists of a film sprocket to the axis of which is attached a large graduated circle with vernier scale. As this sprocket is turned the film is pulled through the punching die and the distance between successive openings can be read in terms of the number of edge perforations to within .01 of an edge perforation interval.

Since it was desirable to operate several exposing machines at the same time, a central station (Fig. 5), consisting of a multiple timing device was constructed, thus utilizing one governed motor for driving several contact makers. The governed motor *A* is connected through a worm and worm wheel and a pair of spur gears of a ratio of 1 to 1 to a long counter-shaft on which are mounted three film sprockets, *B*, *B*, *B*, running free on the counter-shaft. Near each sprocket and fixed to the counter-shaft is mounted an iron-clad magnetic clutch, the soft iron armature of which is attached to the film sprocket. When any one of these magnetic clutches are energized the corresponding armature is seized, thus causing the attached film sprocket to rotate at the same angular velocity as the counter-shaft. The speed of the motor and gear ratios are so adjusted that the film bands *E*, *F* and *G* are drawn through the contact makers at the rate of four edge perforations per second. The fourth clutch, *K*, is mounted on a separate counter-shaft connected to the main counter-shaft by interchangeable spur gears of such ratios that velocities of 1, 2, 4 8 or 16 edge perforations per second may be imparted to the film band *H* at the will of the operator, thus permitting the total time of exposure to be varied over wide limits. In case further range of variation is desired, the pair of spur gears *D* may be changed, giving either four times, or one-fourth of the standard rate of rotation, to the main counter-shaft. The motor, counter-shafts, and contact makers are mounted on a heavy cast-iron base *L*, forming the bottom of the oak cabinet which houses the entire

central station. On a shelf above are mounted four relays and the eight-volt dry-cell battery *M* furnishing the electromotive force for the primary relay circuits. In the rear of the cabinet are the four film containers *R*, containing the film of the various timing tapes. In these containers the film is looped back and forth over rollers mounted at the top and bottom of the boxes, each container having a capacity of about seventy feet of film. The film records after being punched are made into continuous

Fig. 5.



bands by splicing the ends together. They are then placed in the containers which are shifted into position, a loop of the film being pulled out, threaded through the contact makers and over the guide rollers as shown in Fig. 5. A spring tension is provided inside each container so that all slack is automatically taken up, causing the film to run uniformly, thus making more certain satisfactory operation of the contact makers. By lowering the hinged doors *N*, all of the mechanism is inclosed in a dust-proof case.

As was stated previously, it is necessary to shut off the exposing light at the proper instant. This is accomplished by means

of a pair of auxiliary contacts on the contact maker, slightly offset from the central line of openings. A single opening *G*, Fig. 3, in the film band is punched at the proper distance from the last of the main series of openings and offset so as to come into position over the auxiliary contacts. This pair of contacts is arranged so that the film band when in position in the contact maker depresses the end of the pivoted lever, the other end of which presses against the contacts holding them together. When the offset opening *G* comes into position over the end of the lever the pressure is released, the contact part thus opening the electric circuit. Through this circuit flows the current which energizes the magnetic clutch, causing the film sprocket to rotate and in series with the clutch is a solenoid used for cutting off the exposing light. In case an acetylene burner is used as a source, this solenoid when energized holds open a shutter placed between the burner and the plate to be exposed. The breaking of this circuit by the coming into position of the opening *G* de-energizes the solenoid, allowing the shutter to close instantly under the action of a coiled spring. At the same time the clutch is released, causing the film band to stop in position for the next series of exposures. The acting edge of lug *B*, Fig. 4, is precisely aligned with that of the lever operating the auxiliary contacts, so that in punching the film record the position of the leading edge of opening *G*, relative to that of *F* (the last of the central series) can be accurately determined by means of the punching die used for spacing the central series of holes. This is accomplished by constructing the punching die so that the punch can be offset in a direction exactly perpendicular to the linear axis of the film strip and by an amount such as to bring the offset hole over the auxiliary contact of the contact maker. Fig. 3 is a contact print from a portion of one of the film bands actually used. The direction in which it travels through the contact maker is indicated by the arrow. The dimension lines are drawn to the leading edge of each opening which are so spaced as to give a series of exposures, increasing by consecutive powers of two. This record, run at four perforations per second, gives exposures of .312, .625, 1.25, 2.50, 5.00 and 10.0 seconds' duration.

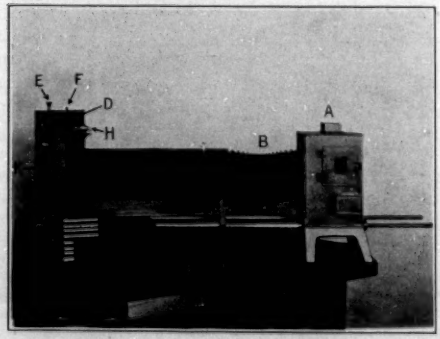
It is evident that any desired series of exposures may be given by proper spacing of the openings in the film bands. This flexibility constitutes one of the chief advantages of this type of timing device.

THE EXPOSING MACHINE.

In Fig. 6 is shown one of the complete exposing machines, *A* being the lamp-house inclosing the standard acetylene burner, and the shutter which terminates the exposure, together with its operation solenoid. The extension bellows *B*, providing for the adjustment of the lamp distance, connects the lamp-house with the extension box *C*, which is fitted with filter holders, carrying the acetylene to daylight filter, or any other filter or filters that it may be necessary to use.

The housing, *D*, incloses the shutter plate, the mechanism

Fig. 6.

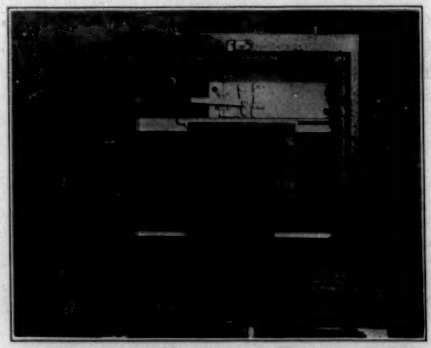


for its operation and the plate holder slide. *H* is a small pilot light in series with the magnetic clutch of the timing mechanism and the solenoid operating the lamp-house shutter serving when lighted as an indication that the mechanism is operating. The starting key *E* is a tapping key of the ordinary type wired in parallel with the auxiliary contact of the timing mechanism. When this key is depressed the magnetic clutch is energized, pulling the film forward, thus displacing hole *G*, Fig. 3, and closing the auxiliary contact. Key *E* can then be released without opening the clutch circuit, the clutch remaining energized until hole *G* again comes into position under the auxiliary contact. The member *F* releases the mechanism so that the shutter plate may be pulled back to its initial position for starting a series of

exposures. K is the plate holder slide and L the plate holder used in this particular instrument. In Fig. 7 is shown an end view of exposing machine opened so as to disclose the shutter plate and the operating mechanism above. The solenoid S, being energized by the timing device, furnishes the power for moving the shutter plate.

The shutter plate moves in the horizontal direction and through a distance of 1 cm. at each impulse. The openings in the front of the plate holder are 10 cm. long by 1 cm. wide, giving an exposed area of these dimensions on the photographic plate,

FIG. 7.



each strip consisting of ten steps, each 1 cm. square. It will be noted that the shutter plate used in this machine has two projecting portions YY, on the right-hand edge. These are 3 cm. long and are so spaced relative to the openings in the plate holder that the upper opening of each group of four is covered by the projecting portions. At the start of the exposing operation the edge X is coincident with the edges of the opening in the plate holder, thus completely protecting the photographic plate from the action of the exposing light after the dark slides of the plate holder are pulled out. Exposure of three strips of each group of four begins with the first impulse while the other two strips are protected by the projections YY, until the application of the fourth impulse. This arrangement is provided in order that one strip of

each group of four shall receive only one-eighth as much exposure as the other three.

A tablet consisting of strips of the standard tricolor filters *A* (red), *B* (green), *C* (blue), and Dummy, is placed inside the plate holder, the dummy filter being over the opening lying behind the projections on the shutter plate. This instrument is used for the determination of the exposure factors of color sensitive materials for the tricolor taking filters and is known as the tricolor sensitometer. In the instruments used for ordinary speed testing, a shutter plate with a straight edge is used, the projections being unnecessary when all the strips being exposed are to receive equal exposures.

In Fig. 8 is shown the wiring diagram of the complete apparatus, the circuits of the exposing machine being shown to the right of the figure and those of the central station timing mechanism at the left. In order to simplify the description of this figure the meaning of each symbol will be given in tabular form as follows:

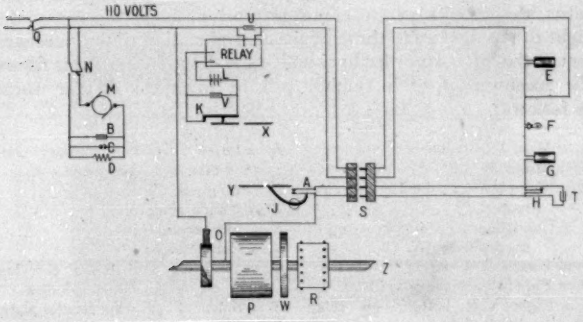
Q = Main line switch.
N = Motor switch.
M = Constant speed governed motor.
B = Condenser for suppression of spark on gap *C*.
C = Governor contacts.
D = Shunted resistance coil.
L = Eight volt battery on relay circuit.
K = Main contact of contact maker.
V = Condenser to choke spark at *K*.
U = Condenser to choke spark on relay contact.
X = Portion of film band.
Y = Portion of film band.
A = Auxiliary contact.
J = Lever operating auxiliary contact.
P = Magnetic clutch.
W = Clutch armature.
R = Film sprocket.
Z = Countershaft.
O = Slip ring and brush carrying current to clutch winding.
E = Solenoid operating shutter plate.
F = Pilot lamp.
G = Solenoid operating lamp-house shutter.
H = Starting contact.
T = Condenser for choking spark at *H* and *A*.
S = Four point plug connector.

In Fig. 8 are shown the circuits for a single instrument and these circuits are duplicated for each additional unit. One part of the four plug connectors, *S*, is mounted on the central station cabinet, the other being wired to the end of the cable leading to the exposing machine. The connections are made interchangeable so that any one of the exposing machines may be plugged in on any

one of the four timing mechanisms in the central station, making a very flexible and convenient arrangement.

In Fig. 9 is shown a special sensitometer built on the same principle as the ones just described. This is built to be used in a dark room and is for convenience provided with its own governed motor *A*, and contact maker *C*, although it may also, if desired, be operated from the central station, shown in Fig. 5. The exposing machine is at *B* and the light source in the housing *D*. In Fig. 10 is shown a detail of the shutter plate, the mechanism for its operation and the holder for the sensitive material to be exposed. This was constructed primarily for the testing of

FIG. 8.



photographic printing papers and takes an 8 x 10 sheet of the material. The paper is placed in position in front of the board *E*, which is then turned into a vertical position and locked, holding the sheet of paper in place during exposure. In case it is not desired to expose the entire surface, a suitable template with narrow vertical openings, or with a series of small circular apertures, may be placed in the holder before inserting the sensitive material. In this way sensitometric exposures may be impressed near the edges of a sheet while the centre is reserved for printing from a negative, thus giving, when developed, the sensitometric characteristic and a picture upon the same sheet of sensitive material and also assuring identical treatment in the development of the two. The mechanism is so arranged as to give twenty-five expos-

Fig. 9.

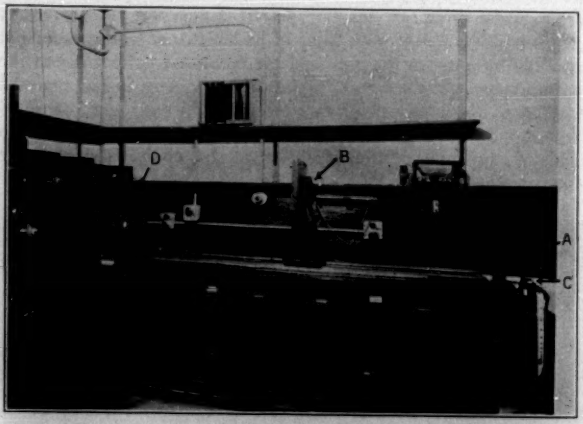
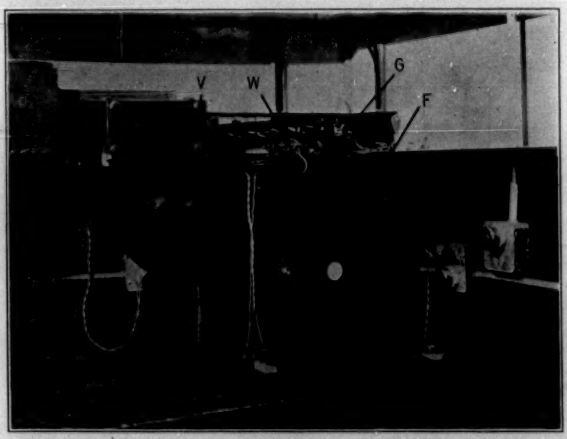


Fig. 10.

ure steps and since papers as a rule have relatively short scales, film records giving a series of exposures, increasing by powers of $\sqrt{2}$ or $\sqrt{3}$, are usually used in order to provide a sufficient number of points for the precise determination of the shape of the characteristic curve. Photographic plates, 8 x 10 inches, may be exposed in this machine with equal facility. A detail view of the lamp-house is shown in Fig. 11. An electric incandescent lamp inside the housing illuminates a sheet of opal glass (10 x 12

FIG. 11.

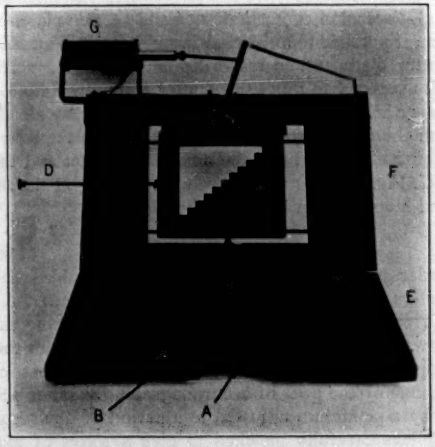


inches), set in front of the lamp-house behind the door frame *F*. A set of metal plates of the same dimension as the opal glass is provided in which are cut circular apertures of various dimensions, the area of the aperture increasing from plate to plate by powers of 2. Any one of these may be held in position over the opal glass thus limiting the effective area of glass used as a source. In order to still further vary the intensity of illumination incident on the material being exposed, the distance between the opal glass and the exposing machine may be varied and read from a scale attached to the track on which the exposing machine moves. The solenoid *G* (equivalent in function to *G*, Fig. 88) terminates the

exposure at the proper instant, not by operation of a shutter, as in the case of instruments using the acetylene as a light source, but by opening the switch *W*, through which current flows to the lamp in the lamp-house and to the operating motor. The starting contact is at *H*, the rheostat controlling the lamp current is operated by the hand wheel *K*, and voltage applied to the lamp used as source is read from the voltmeter *V*.

In Fig. 12 is shown another variation of the same type of

Fig. 12.



sensitometer, a stepped shutter plate *C*, being used instead of the straight edge type employed in the instruments previously described. The plate holder carrying the photographic plate is inserted at *A*, in the hinged back *E*, which in use folded up against the frame *F*, thus holding the photographic plate in position directly behind the shutter plate *C*. Exposure takes place through the slot *B*. The shutter plate *C*, when either in the initial or final positions, completely covers slot *B*, thus protecting the sensitive material from action of the exposing light. Each time the solenoid *G* is energized the shutter plate is moved one step to the right. Handle *D* is provided for pulling the shutter plate back

to its starting position. This type has the advantage that no auxiliary device for terminating the exposure at a precise instant of time is necessary, this being done by the last of the series of impulses applied to the solenoid by the contact maker which moves the shutter plate into a position such that it covers the slot *B* through which exposure takes place. On the other hand, it has the disadvantage that only one strip can be exposed at a time, which is a serious objection where it is necessary to expose a large number of strips. The number of strips exposed simultaneously could be considerably increased by increasing the horizontal dimension of each step of the shutter plate, but such procedure, if pursued to any extent, would result in an excessively long shutter plate and increase the burden of the solenoid by making it necessary to move the shutter plate through a considerable distance at each impulse. This instrument may also be operated from the central station, shown in Fig. 5, the solenoid, *G*, Fig. 5, being eliminated and the auxiliary contact and the offset opening *G*, Fig. 3, being used merely to de-energize the magnetic clutch and stop the movement of the film band.

PERFORMANCE TEST.

In order to determine the precision obtainable with these sensitometers the following series of tests were made. A pair of contact prints were mounted on one of the exposing machines in such a way that the movement of the solenoid under the action of the impulse from the contact maker closed an electric circuit operating one of the pens of a chronograph, the other pen being operated by a pendulum adjusted to a period of one second. A film band was carefully punched to give a series of exposures increasing by powers of 2. This was placed in position and three complete runs made, the time intervals being determined by comparing the records made by the two pens on the chronograph sheet. When operated at normal speed the second interval on the chronograph was about 1 cm. long. This gave sufficient precision for time intervals greater than four seconds, but for shorter times the chronograph drum was geared up so as to give distance of approximately 5 cm. per second. In the following table are given the results of three independent sets of values determined in this way, the group of longer time intervals being determined with the chronograph operating at normal speed and those relative to

shorter intervals with the drum rotating approximately five times as fast. It will be noted that in the first group the mean error is +.25 per cent., while in the group of shorter intervals the mean error is −.35 per cent. The fact that all of the errors in the first case are positive is due to the fact that the governed motor was running at slightly too low a speed, while in the case of the shorter periods, an effort having been made to correct the error noted, the speed was slightly too great. The main difficulty in obtaining precisely timed intervals seems to lie in the adjustment and performance of the constant speed motor rather than in the perforation of the tape and action of the contact-making mechanism. However, the errors shown in Table I are so much smaller than other errors encountered in sensitometric work as to be quite negligible.

Table I.

Computed Values	Observed Values (Records) 1st	2nd	3rd	Mean	Error per cent
128 seconds	128.1	128.3	128.3	128.2	+.16
64 seconds	64.10	64.15	64.16	64.14	+.22
32 seconds	32.07	32.08	32.12	32.09	+.28
16 seconds	16.01	16.03	15.99	16.01	+.06
8 seconds	8.03	8.01	8.02	8.02	+.25
4 seconds	4.00	4.04	4.03	4.02	+.50
				Mean	+.24
8 seconds	8.00	7.98	7.98	7.99	−.12
4 seconds	3.99	4.00	3.98	3.99	−.25
2 seconds	1.99	1.98	1.99	1.99	−.50
1 second	0.996	0.992	0.998	0.995	−.50
0.5 second	0.496	0.497	0.500	0.498	−.40
				Mean	−.35

COMPARATIVE RESULTS.

As stated previously, it was found when using the sensitometers of the sector-wheel type giving intermittent exposures, that an increase or decrease in the exposure time did not produce a proportional increase or decrease in the speed values obtained. Such discrepancies are due to the intermittency effect, the existence of which is well known. (See previous references 12, 13, 14 and 15.) These errors are eliminated by use of the non-intermittent exposing machines described in this paper. That no such effect can exist with this type of instrument is entirely obvious from a theoretical consideration of the subject, but in order to

prove the point experimentally a series of tests were made, using record tapes punched to give different exposure times. All gave exposures increasing by powers of 2, the first or normal (N) giving an exposure of 80 seconds to the area of maximum exposure. In the cases of the other record tapes used No. 2 ($2N$) gave 160, No. 3 ($4N$) gave 320, and No. 4 ($8N$) gave 640 seconds to the corresponding areas of the sensitometer strips. The results are shown in Table II.

TABLE II.

No.	Tape	Time (Max.)	Speed	ΔS	γ	$\Delta\gamma$
1	N	80	10.8	+.25	0.92	−.06
2	$2N$	160	10.6	+.05	1.00	+.02
3	$4N$	320	10.4	−.15	1.00	+.02
4	$8N$	640	10.4	−.15	1.00	+.02
Mean			10.55		.98	

It will be noted that both speed and gamma values are independent of absolute value of the exposure time.

The results of a similar series of tests made on the intermittent sensitometer are shown in Table III, together with a determination made on the non-intermittent machine. It will be noted that a decided decrease in speed occurs as the exposure time is increased, while the gamma values for fixed time of development increase slightly. The speed obtained by non-intermittent exposure is higher than any measured by the intermittent method, while the gamma value is decidedly less.

TABLE III.

No.	Exp.	Time (Max.)	Speed	γ
1	$\frac{1}{8}N$	10	107.0	2.12
2	$\frac{1}{4}N$	20	95.5	2.19
3	$\frac{1}{2}N$	40	83.8	2.23
4	N	80	73.0	2.27
5	$2N$	160	60.8	2.25
6	$4N$	320	49.5	2.29
		Non-intermittent.		
7	N	80	125.4	1.43

In Fig. 13 is shown the general relation between the characteristic curve determined on the sector-wheel sensitometer and that obtained by the non-intermittent method (Fig. 13), curve B being that given by the former and A by the latter instrument.

It will be noted that the density difference between the two curves becomes greater as the exposure diminishes. It will be remembered that the sector-wheel diminishes the exposure from step to step by use of slots of smaller and smaller angular dimensions, so that the ratio of the rest interval to the exposure interval for each revolution of the sectors become greater toward the low exposure end of the strip. The loss of density due to intermittency is therefore proportional to the ratio of rest to exposure. This is in agreement with the work of Schwarschild and Abney (*loc cit.*).

The magnitude of the intermittency effect varies to a great extent for different kinds of plates. This is shown by the data given in Table IV. The various plates used are designated by letter as follows:

A. Very slow ordinary.
B. Very slow ordinary.
C. Medium speed panchromatic.
D. Medium speed ordinary.
E. Fast ordinary.
F. Fast ordinary.

Table IV.

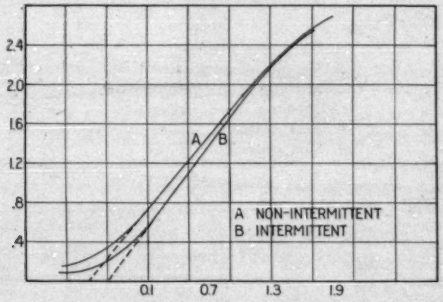
Time (Max.)	A	B	C	D	E	F
20	...	...	131	115	107	210
40	...	...	115	108	103	140
80	100	100	100	100	100	100
160	99	93	83	90	96	75
320	97	83	68	79	90	55
Non-intermittent.						
80	103	100	171	107	102	189

The speed values obtained by the sector-wheel sensitometer with normal exposure are in each case taken as 100, and all others expressed relative to those values.

The data given in Tables II, III and IV serve to show the relative performance of the sector wheel and non-intermittent instrument. It will be noted that a considerable discrepancy exists between the relative values determined with the non-intermittent sensitometer and those determined by means of the sector-wheel instrument. Further, that the relative values determined by the sector instrument are dependent upon the absolute value of the exposure time taken as a standard.

The sensitometers of Type 2, Class B, described in this paper, have been in use in this Laboratory for some time. Some of them were constructed as early as 1916, and have been in continuous use since that time. In general, they have proven extremely satisfactory, although of course certain defects were present in the first models constructed. Although a certain amount of attention is required to keep them in good running condition, they have not given much trouble in that respect, and do not require highly skilled operators. The instruments operated from the central station, shown in Fig. 5, are especially adapted for routine work and are almost entirely automatic in their action,

FIG. 13.



it only being necessary to close the main switch supplying the current to the 110 circuit and to depress the working key on the exposing machine. The action from that time on is entirely automatic and is automatically terminated, when the desired series of exposures has been impressed on the photographic plate.

The data presented in this paper are fragmentary and not intended as a treatment of the subject on the intermittency effect, but only to illustrate the difference between the results obtained with sector wheel and non-intermittent sensitometers. A considerable amount of data has already been accumulated which, together with the results of further work now in progress, the author hopes in the near future to present in a paper dealing with the general subject of intermittency.

In closing, the author desires to acknowledge his indebtedness

to Dr. W. W. Sleator for the chronographic tests of the timing mechanism and to Mr. Emory Huse for the experimental work in obtaining the sensitometric data given in the latter part of the paper.

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Rochester, N. Y.,
September 13, 1919.

French Railroad Construction During the War. (*La Nature*, January 3, 1920.)—The war naturally stopped all extensions of railways except those of great importance. There were two new lines completed on the Paris-Lyons-Mediterranean System. The first runs from Frasne, Department Doubs, to Vallorbe in Switzerland. It shortens the route from Paris to Milan. Though its length is only 15 miles, two considerable difficulties of construction had to be overcome. The marsh of Sainte-Marie had peat and mud to a depth of 200 feet, and was crossed on a filling of rocky material resting on the quagmire, which was forced into waves on both sides of the line. Mont d'Or was pierced by a tunnel more than three miles long. At one place a flow of water amounting to 1300 gallons per second was encountered, and later a second flow of twice the former amount interfered with operations.

The other line finished in war time was near Marseilles and completed a second trunk line from Paris to the Mediterranean port. Its outstanding feature is a metallic viaduct across the Lake of Caronte of half a mile length with a turn-bridge at the maritime canal.

G. F. S.

The Detection of Invisible Objects by Heat Radiation. S. O. HOFFMAN. (*Phys. Rev.*, August, 1919, p. 163.)—In 1918 the United States Army started to devise methods for detecting men and inanimate objects which were at a higher temperature than adjacent things by means of the emitted radiation. A thermopile was placed at the focus of a parabolic mirror. The radiation from the warmer object fell on the mirror and was reflected to the thermopile where it produced an electric current which was observed by means of a galvanometer. It was possible to detect a man 600 feet away. "A man lying in a depression in the ground at a distance of 400 feet was detected unfailingly as soon as he showed the upper part of his face above ground." Secret signalling could be carried on by covering and uncovering the face. This apparatus was sent to the A. E. F. in August, 1918.

An aeroplane at an altitude of 3500 feet could be picked up by such an instrument and its course followed. A wisp of cloud produced confusion by causing as large a deflection as the aeroplane did, but the two possible causes were different in the way in which the galvanometer deflection began.

G. F. S.

The Use of Electricity in Agriculture: With Special Reference to Its Development in Germany. J. F. CROWLEY. (*Journal of the Royal Society of Arts*, October 10, 1919.)—There has been an astonishing increase in the application of electricity to agricultural operations in Germany during the present century. In Saxony, at least, electricity was thus employed to a larger extent by small or moderate holders rather than by large farmers. Rural coöperative societies are common. In 1901 there was one; in 1913 more than 600. Some societies develop electrical current themselves, while others merely distribute it.

On each hundred acres of cultivated land:

(1) The British farmer feeds from 40 to 50 persons, the German farmer feeds from 70 to 75 persons.

(2) The British farmer grows 15 tons of corn, the German farmer grows 33 tons.

(3) The British farmer grows 11 tons of potatoes, the German farmer grows 55 tons.

(4) The British farmer produces 4 tons of meat, the German farmer produces 4¼ tons.

A chief factor in favor of the German farmer is his increased use of artificial fertilizers.

G. F. S.

In the *Journal of the Royal Society of Arts* for October 17, 24, and 31, 1919, is published a series of three Cantor lectures on "Coal and Its Conservation," by WILLIAM A. BONE. It will be remembered that this eminent authority lectured at THE FRANKLIN INSTITUTE a few years ago.

THE RELATIVE MERITS OF MONOCULAR AND BINOCULAR FIELD-GLASSES.* †

THE RESULTS OF AN INVESTIGATION UNDERTAKEN BY THE SUB-COMMITTEE OF THE NATIONAL RESEARCH COUNCIL ON "MONOCULAR *versus* BINOCULAR FIELD-GLASSES."

BY

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P. W. COBB,
H. M. JOHNSON,
W. WENIGER.

PART III.

Field Tests at Camp Meade, Maryland.

The work herein reported consists of practical field tests conducted with monocular and binocular glasses of identical optical design. The binoculars were of the type EE, Bausch & Lomb Co., 6-power, the left limb being fitted with a mil scale and an Eames aiming scale. For the purpose of a strictly comparative test this last detail is superfluous and undesirable, presumably causing a certain interference with vision to an undetermined degree not present in the case of the monoculars, but it had to be admitted since there were no other glasses available. The monoculars were without this, being exactly like the right limb of the binoculars devoid of all (to them) superfluous parts.

The tests were four in number:

(1) A general daylight test, in which a single man was the object of vision,

(2) A twilight test, similarly planned, but carried out late in the day until terminated by darkness,

(3) A counting test, in which groups of men varying in number appeared at stated places, and

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* Communicated by Edward P. Hyde.

† Concluded from p. 223, Vol. 189, February, 1920.

[1] The Committee is indebted to Messrs. Cobb and Weniger for practically all of the experimental work.

(4) A timing test, in which the time was determined required to get the glass from the place where it is usually carried and report on an object resolvable only with the glass.

In addition, one other item is here discussed.

(5) The opinions of the observers as to the relative advantage of the two types of glasses and their reasons for the same.

For the first three of these, the observers, forty-eight in number, or a few less than this, were officers ranking from second lieutenant to captain. As nearly as possible, one-half of this number were equipped with binoculars, the other half with monoculars; exchanges were made in the course of the work in such a way as to give each observer the same amount of work with each, and to have his work with each of the two types of glass distributed as nearly as possible in the same way over the whole course of experimentation.

The purpose of the test was explained to the observers and detailed instructions were given them concerning the adjustments of the two types of glass and the method of holding each so as to obtain maximum steadiness by resting the fingers against the forehead or against the forehead and nose. Special stress was laid on the fact that when using the monocular the eye not in use should be kept open to avoid eye-strain, as well as to induce the least disturbance of the pupil; and that the best means of accomplishing this and, at the same time, of permitting focussing and attaining maximum steadiness was to hold the monocular with the objective at higher level than the eye-piece, using the left hand for the right eye or *vice versa*, thus bringing the wrist in front of the unused eye, placing the little finger below the objective mounting, the second and third fingers on the top of the instrument and gripping the eye-piece housing between the forefinger and thumb.

The visual objects upon which these three tests depend were men in khaki uniform, eleven in number, ten privates and one sergeant. They appeared at fixed points in the field, according to a prearranged program which was not the same for any two runs. For tests (1) and (2), however, the general plan of the program was the same, and it will be described in detail once for both.

The ground used for tests (1), (2), and (3) lies in the eastern part of Camp Meade, the observers being located (see map, Fig. 10) on the top of a low, broad hill situated in the bend of the

concrete road which leads eastward from the W. B. & A. loop station and turns toward the north. The observers looked in a northerly direction, somewhat easterly, and were given complete freedom in choosing their posture. Many of them were seated on camp chairs and other suitable articles after the first day. The appearance of the landscape is shown in the photograph (Fig. 11) where also are shown the various locations of the men who acted as visual objects, designated by capital letters. The location of these stations is similarly indicated on the map.

In the daylight and the twilight work, tests (1) and (2), but one man appeared at a time, coming from a concealed position to his designated place of exposure, according to schedule, standing there facing the observer for fifty seconds, and then either raising an arm to the horizontal or aiming a rifle, to the left or to the right as the schedule called for, for ten seconds. This applies to the men at Stations *A, B, C, D, E, F, G,* and *H*. The man at *E* was located in the woods and could only be seen between the tree-trunks. His action consisted in walking a certain exposed beat for one minute, either without a rifle or with a rifle at right shoulder. In the cases of *X, Y,* and *Z* the action consisted in either aiming a rifle or pointing with the hand at the observers.

The conditions as to distance, background, etc., under which the men at each of these stations was to be seen are given in the following summary:

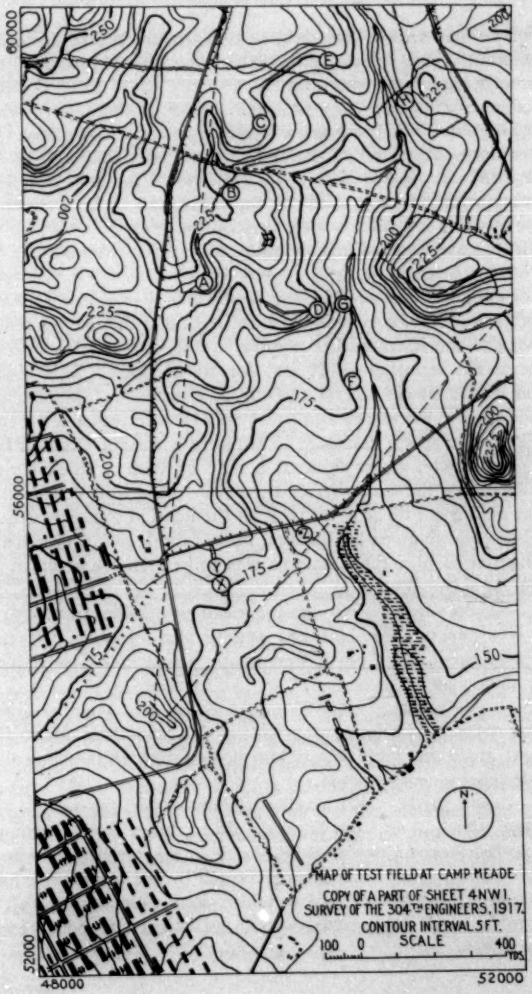
A—1180 yards. Seen against meadow hillside about 150 to 200 feet beyond him. Stands among small bushes, not concealed by them. Not much stereoscopic effect noted on viewing with binoculars.

B—1440 yards. Concealed from waist line down by intervening elevation; background is a spur of the wood about 100 feet beyond, appearing quite near to him as seen through the binocular. No stereoscopic effect noted.

C—1650 yards. Full length; background up to waist is the meadow which rises from his feet, above that a darker ground, apparently cleared forest bottom. Little or no stereoscopic effect.

D—1190 yards. Concealed to crotch by the trench in which he stands. Background is a meadow slope estimated from the map to be about 500 yards beyond. Distinct to good stereoscopic effect.

FIG 10.


60000
56000
52000
48000
52000
250
225
200
175
150
A
B
C
D
E
F
G
X
Y
N
MAP OF TEST FIELD AT CAMP MEADE
COPY OF A PART OF SHEET 4NW1.
SURVEY OF THE 304TH ENGINEERS, 1917.
CONTOUR INTERVAL 5 FT.
100 0 SCALE 400
FEET

E—1850 yards. In wood, rather deeply in. Concealed in part of his beat, sometimes entirely visible between tree-trunks. No stereoscopic effect.

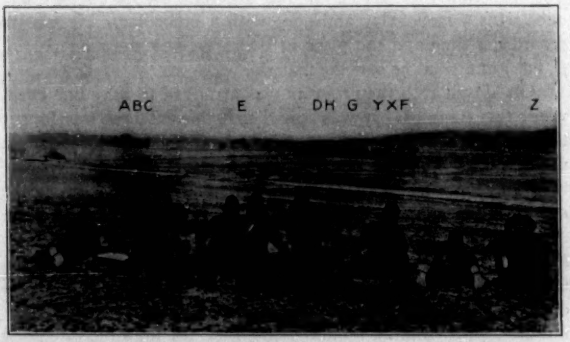
F—1055 yards. Concealed crotch-high.

G—1230 yards. Concealed to mid-thighs.

F and *G* are both concealed, as above, by intervening swells in the meadow. Background conditions also about alike; nearly level meadow. Little or no stereoscopic relief.

H—1800 yards. Completely exposed. Seen against the slope which ascends easily behind him. No stereoscopic effect.

FIG 11.



Experimental field. Stations are indicated by circles and letters. Note: Second observer from left is holding monocular incorrectly.

X—410 yards. Concealed to an oblique line, about breast-high, by the hedge. Background about as for *Y*.

Y—420 yards. Nearly full length, screened by the hedge, especially below. The details of the hedge are seen with fair stereoscopic effect against the level meadow beyond.

Z—630 yards. Concealed breast-high by intervening elevation when standing in the open at the northwest or southeast corner of a house. In half of his events *Z* appeared in the west or south window of the house. As the outside and inside conditions are not at all comparable as to light, background, etc., the latter have, in the report, been given the separate designation *Z'*.

(1) THE DAYLIGHT TESTS.

The daylight tests were run on four days: March 18th, from 2 P.M. to 5 P.M., and March 19th, 20th, and 26th, from 2 P.M. to 4:30 P.M. Each man who acted as visual object appeared eight times each day. The two postures, raising the arm and aiming the rifle, and the two directions, east and west, making four possibilities for most of the men. A program was arranged consisting of four events for each man—forty-four events in all in shuffled order—and after a short intermission in which monoculars and binoculars were exchanged by the observers the whole forty-four events were repeated in reverse order. Thus each observer had the opportunity of seeing all the different events of that day once with a monocular and once with a binocular. He was to record the time and the place at which he saw the man (*A*, *B*, *C*, etc.) and what he saw the man do.

On March 18th the program was arranged to have one event every two minutes. It was found that this interval was longer than was necessary. For the other days and for the twilight work it was shortened to ninety seconds. This gave adequate time for recording and had the further advantages of keeping the observers more interested and shortening the whole time of work. As was to be expected, on the first day a considerable portion of the time, at first, was required for the observers to learn the stations. To facilitate this all the men out in the field were required to be in their respective exposed positions for fourteen minutes, until within a minute of the time for the first scheduled event. More or less confusion was, however, inevitable, especially as there were many other men, extraneous to this work, about the field engaged in various kinds of practice. As a result the records showed many entries which proved by comparison with the schedule to be irrelevant and had to be excluded. These things disappeared rapidly as the work went on. The observer's problem then became simple: he had to watch eleven points in the landscape and report in his record the time, place and action when a man appeared at any one.

Table XI is a general summary of these results. In compiling this table certain eliminations had to be made in advance in order that the results might apply equally to monoculars and binoculars. On the first day there was delay in learning the field, and the

program was too long and had to be cut short at the end. Fortunately, since the second half of the program was exactly the reverse of the first, the resulting deletions did not involve much valuable material. Again, there was delay, after the intermission, in getting the observers back to work. This showed itself in the summary for the day and the necessary deletions could be estimated and equalized. In a few cases other duties or circumstances made the record of a single observer incomplete. The first consideration in making these deletions was always to make the total number of experiments equal and identical for the two glasses; the second was to have each observer's final record represent equal numbers of experiments with the two. It was only to the slightest extent that the second could not be realized. The following figures have reference only to the remaining experiments considered in Table XI and such other things as occurred while these were in progress.

	Monocular	Binocular
Experiments considered	7,174	7,174
Total records	5,005	5,295
Records considered	4,726	5,047
Records rejected as extraneous	279	248

This speaks at once in favor of the binocular, in two ways. Out of a total of 7174 possibilities the number of times that the test objects were seen is more numerous by 321 (5047 − 4726), or 4.5 per cent. of the possibilities. In addition, the records not applying to the test objects of the experiments are less numerous with the binocular by 31, indicating, if anything, that the problem of learning the field was simpler with the binocular.

EXPLANATION OF TABLES XI AND XII.

Column Headings.

A, B, C, etc.—Designations of stations.

S – Observation of the man at Stations *A, B, C,* etc.

ew – Discrimination of the direction of action (aiming or extending arm) at right angles to the observer's line of sight. See also explanation of line heading "results."

TABLE XI.

Daylight Results, Camp Meade, March 18 to 26, Arranged According to Calendar Days.

		A						B						C					
		Monocular			Binocular			Monocular			Binocular			Monocular			Binocular		
		S	ew	ro	S	ew	ro	S	ew	ro	S	ew	ro	S	ew	ro	S	ew	ro
Mar. 18	Experiments	95	95	95	95	95	95	95	95	95	95	95	95	143	143	143	143	143	143
	Results	79	45	43	80	53	49	29	7	2	28	13	12	115	29	2	119	42	0
	Percentages	83.1	57.0	54.4	84.2	66.2	61.3	30.5	24.2	6.9	29.4	46.4	42.8	80.4	25.2	1.7	83.2	35.3	0.0
Mar. 19	Experiments	176	176	132	176	176	132	175	175	175	175	175	175	175	175	175	175	175	175
	Results	163	114	75	162	118	83	45	13	6	57	29	27	158	28	28	168	53	47
	Percentages	92.6	70.0	61.3	92.1	72.9	68.2	25.7	28.9	13.3	32.6	50.9	47.4	90.2	17.7	17.7	96.0	31.5	28.0
Mar. 20	Experiments	188	188	188	188	188	188	186	186	186	186	186	186	188	188	188	188	188	188
	Results	175	123	87	177	146	90	48	15	18	56	22	24	179	68	59	183	81	79
	Percentages	93.1	70.2	49.7	94.2	82.5	50.9	25.8	31.3	37.5	30.1	30.3	42.8	95.2	38.0	33.0	97.4	44.2	43.1
Mar. 26	Experiments	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172
	Results	145	67	68	156	93	105	89	27	21	92	34	27	151	33	12	154	56	40
	Percentages	84.3	46.1	46.9	90.7	59.6	67.3	51.7	30.3	23.6	53.4	37.0	29.4	87.7	21.9	8.0	89.5	36.4	26.0
Totals results	Experiments	631	631	587	631	631	587	628	628	628	628	628	628	678	678	678	678	678	678
	Results	562	349	273	575	410	327	211	62	47	233	98	90	603	158	101	624	232	166

		D						E				F					
		Monocular			Binocular			Monocular		Binocular		Monocular			Binocular		
		S	ew	ro	S	ew	ro	S	ro	S	ro	S	ew	ro	S	ew	ro
Mar. 18	Experiments	143	143	143	143	143	143	190	190	190	190	190	190	190	190	190	190
	Results	79	46	34	100	77	54	42	2	56	3	71	39	34	71	34	30
	Percentages	55.2	58.2	43.0	69.9	77.0	54.0	...	...	...	...	37.4	55.0	47.8	37.4	47.8	42.2
Mar. 19	Experiments	179	179	179	179	179	179	178	178	178	178	178	178	178	178	178	178
	Results	157	124	99	159	139	128	10	0	30	1	163	129	98	172	141	129
	Percentages	87.6	79.2	63.0	88.8	87.4	80.5	...	...	...	...	91.5	79.1	60.1	96.6	82.0	75.0
Mar. 20	Experiments	187	187	187	187	187	187	187	187	187	187	187	187	187	187	187	187
	Results	183	156	134	178	163	145	38	0	57	−1	181	152	145	183	167	149
	Percentages	97.9	85.2	73.2	95.2	91.6	81.5	...	...	...	...	96.9	84.0	80.1	97.9	91.2	81.4
Mar. 26	Experiments	129	129	129	129	129	129	129	129	129	129	172	172	172	172	172	172
	Results	79	45	34	84	53	43	51	0	68	1	160	133	123	164	147	140
	Percentages	61.2	56.9	43.0	65.1	63.1	51.2	...	...	...	...	93.0	83.1	76.9	95.3	89.7	85.3
Totals results	Experiments	638	638	638	638	638	638	684	684	684	684	727	727	727	727	727	727
	Results	498	371	301	521	432	370	141	2	211	4	575	453	400	590	489	448

		G						H						X					
		Monocular			Binocular			Monocular			Binocular			Monocular			Binocular		
		S	*ew*	*ro*	*S*	*ew*	*ro*	*S*	*ew*	*ro*	*S*	*ew*	*ro*	*S*	*p*	*ro*	*S*	*p*	*ro*
Mar. 18	Experiments	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143
	Results	52	19	16	79	49	39	63	19	21	69	34	27	91	3	3	87	6	6
	Percentages	36.4	36.5	30.8	55.2	62.0	49.4	44.0	30.2	33.3	48.2	49.3	39.1	63.6	3.3	3.3	60.8	6.9	6.9
Mar. 19	Experiments	179	179	179	179	179	179	134	134	134	134	134	134	177	177	177	177	177	177
	Results	127	73	63	142	108	96	91	27	11	93	33	24	147	28	24	157	41	17
	Percentages	70.9	57.5	49.6	79.3	76.1	67.6	67.9	29.6	12.1	69.4	35.5	25.8	83.0	19.0	16.3	88.7	26.1	10.8
Mar. 20	Experiments	140	140	140	140	140	140	187	187	187	187	187	187	188	188	188	188	188	188
	Results	111	80	74	122	94	91	148	69	49	166	86	60	76	3	3	70	4	4
	Percentages	79.3	72.1	66.7	87.2	77.0	74.6	79.2	46.6	33.1	88.8	51.8	36.2	40.4	3.9	3.9	37.2	5.7	5.7
Mar. 26	Experiments	129	86	86	129	86	86	172	172	172	172	172	172	129	129	129	129	129	129
	Results	95	34	47	100	30	52	160	75	69	157	100	79	110	9	1	115	9	5
	Percentages	73.6	53.7	74.2	77.5	58.5	78.0	93.0	46.9	43.1	91.3	63.7	50.3	85.2	8.2	0.9	89.1	7.8	4.3
Totals results	Experiments	591	548	548	591	548	548	636	636	636	636	636	636	637	637	637	637	637	637
	Results	385	206	200	443	290	278	462	190	150	485	253	190	424	43	31	429	60	32

		Y						Z						Z′					
		Monocular			Binocular			Monocular			Einocular			Monocular			Binocular		
		S	*p*	*ro*	*S*	*p*	*ro*	*S*	*p*	*ro*	*S*	*p*	*ro*	*S*	*p*	*ro*	*S*	*p*	*ro*
Mar. 18	Experiments	144	144	144	144	144	144	96	96	96	96	96	96	95	48	48	95	48	48
	Results	21	5	−1	40	9	5	69	28	28	74	38	36	25	2	2	43	7	7
	Percentages	14.6	23.8	−4.8	27.8	22.5	12.5	71.8	40.6	40.6	77.1	51.4	48.6	26.3	16.0	16.0	45.2	32.3	32.3
Mar. 19	Experiments	177	177	177	177	177	177	88	88	88	88	88	88	90	90	90	90	90	90
	Results	122	62	11	138	88	24	69	17	13	66	16	12	54	5	5	67	5	3
	Percentages	68.9	50.8	9.0	78.0	63.7	17.4	78.4	24.6	18.8	75.0	24.2	18.2	60.0	9.3	9.3	74.4	7.5	4.5
Mar. 20	Experiments	188	188	188	188	188	188	94	94	94	94	94	94	94	94	94	94	94	94
	Results	125	33	19	136	43	35	90	29	27	88	41	35	92	15	7	86	19	15
	Percentages	66.5	26.4	15.2	72.4	31.6	25.8	95.8	32.2	30.0	93.6	46.6	39.8	97.9	16.3	7.6	91.5	22.1	17.4
Mar. 26	Experiments	129	129	129	129	129	129	86	86	86	86	86	86	43	43	43	43	43	43
	Results	85	14	8	86	17	17	82	47	37	80	49	49	31	11	1	32	11	7
	Percentages	65.9	16.5	9.4	66.6	19.8	19.8	95.4	57.3	45.1	93.0	61.2	61.2	72.1	35.5	3.2	74.4	34.4	21.9
Totals results	Experiments	638	638	638	638	638	638	364	364	364	364	364	364	322	275	275	322	275	275
	Results	353	114	37	400	157	81	310	121	105	308	144	132	202	33	15	228	42	32

TABLE XII.

Daylight Results, Camp Meade, March 18 to 26, Arranged According to Days of Practice.

		A						B						C					
		Monocular			Binocular			Monocular			Binocular			Monocular			Binocular		
		S	ew	ro	S	ew	ro	S	ew	ro	S	ew	ro	S	ew	ro	S	ew	ro
I	Experiments	140	140	136	140	140	136	140	140	140	140	140	140	188	188	188	188	188	188
	Results	114	64	58	121	80	52	37	9	3	38	19	18	153	34	9	162	51	8
	Percentages	81.4	56.1	52.3	86.4	66.1	44.2	26.4	34.3	8.1	27.2	5.0	47.4	81.4	22.2	5.9	86.1	31.5	4.9
II.	Experiments	187	187	147	187	187	147	186	186	186	186	186	186	186	186	180	186	186	186
	Results	178	126	83	170	127	104	50	16	11	59	25	24	171	31	30	180	64	58
	Percentages	95.2	70.7	59.4	90.8	74.7	78.0	26.9	32.0	22.0	31.7	42.4	40.7	91.9	18.1	17.5	96.8	35.6	32.2
III	Experiments	156	156	156	156	156	156	154	154	154	154	154	154	156	156	156	156	156	156
	Results	145	103	74	146	119	73	42	14	14	52	24	25	150	66	52	148	73	66
	Percentages	92.9	71.0	51.0	93.6	81.5	50.0	27.2	33.3	33.3	33.8	46.2	48.1	96.2	44.0	34.6	94.9	49.3	44.6
IV	Experiments	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148
	Results	125	56	58	138	84	98	82	23	19	84	30	23	129	27	10	134	44	34
	Percentages	84.5	44.8	46.4	93.3	60.8	71.0	55.4	28.0	23.2	56.7	25.7	27.4	87.2	20.9	7.8	90.5	32.8	25.4
Totals	Experiments	631	631	587	631	631	587	628	628	628	628	628	628	678	678	678	678	678	678
	Results	562	349	273	575	410	327	211	62	47	233	98	90	603	158	101	624	232	166

		D						E				F					
		Monocular			Binocular			Monocular		Binocular		Monocular			Binocular		
		S	ew	ro	S	ew	ro	S	ro	S	ro	S	ew	ro	S	ew	ro
I	Experiments	189	189	189	189	189	189	236	236	236	236	237	237	237	237	237	237
	Results	113	68	56	138	108	67	45	2	63	3	112	68	61	115	71	55
	Percentages	59.8	60.2	44.2	73.0	78.2	48.5	19.1	4.4	26.7	4.8	47.2	60.7	54.4	48.5	61.7	47.8
II	Experiments	188	188	188	188	188	188	187	187	187	187	187	187	187	187	187	187
	Results	175	143	120	171	150	147	13	0	34	1	173	138	113	161	150	140
	Percentages	93.0	81.6	68.5	90.9	87.7	86.0	7.0	0.0	18.2	2.9	92.5	79.8	65.3	96.8	82.9	77.4
III	Experiments	150	150	150	150	150	150	150	150	150	150	155	155	155	155	155	155
	Results	145	120	102	137	125	115	36	0	58	−1	153	133	122	151	140	128
	Percentages	96.6	82.8	70.4	91.3	91.2	83.9	24.0	0.0	38.7	−1.7	98.7	86.9	79.7	97.4	92.7	84.7
IV	Experiments	111	111	111	111	111	111	111	111	111	111	148	148	148	148	148	148
	Results	65	40	29	75	49	41	47	0	56	1	137	114	104	143	128	125
	Percentages	58.5	61.5	44.6	67.6	65.3	54.6	42.4	0.0	50.4	1.8	92.6	83.2	75.9	96.6	89.5	87.4
Totals	Experiments	638	638	638	638	638	638	684	684	684	684	727	727	727	727	727	727
	Results	498	371	301	521	432	370	141	2	211	4	575	453	400	590	489	448

V. 19

		G						H						X					
		Monocular			Binocular			Monocular			Binocular			Monocular			Binocular		
		S	ew	ro	S	ew	ro	S	ew	ro	S	ew	ro	S	p	ro	S	p	ro
I	Experiments	183	182	182	183	182	182	185	185	185	185	185	185	188	188	188	188	188	188
	Results	71	29	22	105	63	49	80	27	25	94	45	33	114	6	4	108	8	4
	Percentages	38.8	41.0	31.2	57.4	60.3	46.9	48.1	30.3	28.1	50.8	47.9	35.1	60.6	5.3	3.5	57.5	7.4	3.7
II	Experiments	181	181	181	181	181	181	148	148	148	148	148	148	187	187	187	187	187	187
	Results	132	80	72	145	111	105	105	31	19	111	41	28	140	27	25	152	40	20
	Percentages	72.9	60.6	54.5	80.1	76.5	72.4	71.0	29.5	18.1	75.0	36.9	25.2	74.8	19.3	17.9	81.2	26.3	13.2
III	Experiments	116	111	111	116	111	111	155	155	155	155	155	155	151	151	151	151	151	151
	Results	103	71	69	106	82	79	132	70	44	146	79	61	75	4	2	69	3	3
	Percentages	88.8	72.0	70.1	91.4	80.8	77.9	85.1	53.0	33.3	94.1	54.1	41.8	49.7	5.3	2.7	45.7	4.3	4.3
IV	Experiments	111	74	74	111	74	74	148	148	148	148	148	148	111	111	111	111	111	111
	Results	79	26	37	87	34	45	136	62	62	134	88	68	95	6	0	100	9	5
	Percentages	71.2	49.3	70.3	78.4	58.5	77.5	91.9	45.6	45.6	90.5	65.7	50.7	85.6	6.3	0.0	90.0	9.0	5.0
	Experiments	591	548	548	591	548	548	636	636	636	636	636	636	637	637	637	637	637	637
Totals	Results	385	206	200	443	290	278	462	190	150	485	253	190	424	43	31	429	60	32

		Y						Z						Z′					
		Monocular			Binocular			Monocular			Binocular			Monocular			Binocular		
		S	p	ro	S	p	ro	S	p	ro	S	p	ro	S	p	ro	S	p	ro
I	Experiments	189	189	189	189	189	189	119	119	119	119	119	119	118	71	71	118	71	71
	Results	43	13	3	66	13	5	87	33	29	92	42	40	41	3	1	62	9	7
	Percentages	22.8	30.2	7.0	34.9	19.7	7.6	73.1	37.9	33.3	77.4	45.7	43.5	34.8	12.1	4.0	52.5	24.2	18.8
II	Experiments	187	187	187	187	187	187	93	93	93	93	93	93	94	94	94	94	94	94
	Results	134	62	11	145	87	27	78	18	18	74	22	18	63	9	7	70	6	4
	Percentages	71.6	46.3	8.2	77.5	60.0	18.6	83.9	23.1	23.1	79.6	29.7	24.3	67.0	14.3	11.1	74.4	8.6	5.7
III	Experiments	151	151	151	151	151	151	78	78	78	78	78	78	73	73	73	73	73	73
	Results	104	28	16	116	42	34	75	31	29	74	38	32	72	12	6	69	17	13
	Percentages	68.8	26.9	15.4	76.7	36.2	29.3	96.2	41.3	38.6	94.8	51.4	43.3	98.6	16.7	8.3	94.5	24.6	18.8
IV	Experiments	111	111	111	111	111	111	74	74	74	74	74	74	37	37	37	37	37	37
	Results	72	11	7	73	15	15	70	39	29	68	42	42	26	9	1	27	10	8
	Percentages	64.8	15.3	9.7	65.8	20.5	20.5	94.5	55.7	41.4	91.9	61.8	61.8	70.2	34.6	3.8	73.0	37.0	29.6
	Experiments	638	638	638	638	638	638	364	364	364	364	364	364	322	275	275	322	275	275
Totals	Results	353	114	37	400	157	81	310	121	105	308	144	132	202	33	15	228	42	32

ro – Discrimination between aiming and extending arm. See also explanation of line heading "results."

p – Mention of action (aiming or extending arm) in the observer's line of sight.

Line Headings.

I, II, III, IV (Table XII only)—Results obtained respectively on the first, second, third and fourth or fifth days of practice with the monocular.

Experiments.—Total number of experiments considered.

Results.—Number of records after eliminating extraneous ones. This includes in columns *S* the total number of answers; in columns *ew* and *ro* the number of right minus the number of wrong answers; in columns *p* the number of records as to action.

Percentages.—In columns *S*, the percentage of observation:

$$100 \times \frac{\text{Number of results}}{\text{Number of experiments}}$$

; in columns *ew*, *ro* and *p* the percentage of discrimination:

$$100 \times \frac{\text{Results } (ew,\ ro,\ p)}{\text{Results } (S)} \times \frac{\text{Experiments } (S)}{\text{Experiments } (ew,\ ro,\ p)}$$

It is a point of importance to know, if possible, just how this result would be affected by practice. It is to be presumed that all of the observers had had practice to a greater or less extent with binoculars, while as to the monoculars the presumption is all the other way. Then in the course of the work it is to be expected that this difference will tend to disappear. In Table XII, therefore, the observers have been grouped, not according to the calendar days of the experiment, as in Table XI, but according to the days which were the first, second, etc., of their individual practice with the monocular in the various parts of this work. A comparison of these two groupings is shown in the following:

Day of Practice	Total	March 18	19	20	26
I	60	48	5	6	1
II	47	..	40	7	0
III	39	..	..	34	5
IV	37	..	..	..	37
		48	45	47	43

Thus, with a total of 60 observers who figure in at least one day's work, there were but 37 who got as far as the fourth. This was, of course, due to the fact that a few of the original forty-eight had to be excused on account of other duties from time to time, their places being taken by a limited number of others. This

might be briefly stated by saying that there were 37 regular observers and 23 substitutes.

A word is to be said as to how the extraneous results were distributed over the various days. First, as to the days of the calendar we have extraneous observations:

March	Monocular	Binocular	Number of Observers	Excess in favor of Binoculars
18	104	97	48	7
19	96	82	45	14
20	56	43	47	13
26	23	26	43	− 3
	279	248		31

Day	Monocular	Binocular	Number of Observers	Excess in favor of Binoculars
I	148	127	60	21
II	75	67	47	8
III	34	28	39	6
IV	22	26	37	− 4
	279	248		31

All of the March 18th records are, of course, included in Day I, and, as has been said, the first portion of the work of that date has not been considered. The decline in the number of extraneous records is therefore greater than would be indicated by the first line of either of the above tables, since the deleted portion contains a more than proportionately large number. The process of learning the field was a rapid one, and the extraneous records of the later dates were practically all due to happenings in the field which could only be differentiated by reference to the schedule.

Before going further, it may be well to state in detail the first step in the analysis of the results. The men at Stations *A*, *B*, *C*, *D*, *F*, *G*, and *H*, fifty seconds after appearing in their respective exposed places, went through the performance of aiming a rifle or raising an arm to the horizontal, either to the east or to the west; that is, at right angles to the observers' line of sight. It soon developed that the observer's record, in addition to the time, which was a check on the relevancy of the report, consisted essentially of three things: (1) the station designation, (2) the direction of action, whether east or west, and (3) the nature of the action, whether the man aimed a rifle or simply raised an arm.

As to (1), there is no apparent way of rating the result except to compare the number of times a given man (test object), *e.g.*, *A*, was seen, with the total number of possibilities of that event. The symbol *S* is used here with reference to this criterion.

(2) As to the report on the direction of the action, there are three possibilities. These are: no report, wrong report, and right report. A wrong report is made, on the face of the matter, in the absence of seeing. With but two possibilities as to the fact, it is equally probable that a right report would be made in the same way, that is, for every wrong answer there are not one, but two "guesses"; and conclusions as to actual seeing are to be drawn from the number of right answers minus the number of wrongs. The symbol *ew* has reference to the seeing of the action, and the values under this head are derived from the right-minus-wrong number of answers as to direction.

(3) The case of differentiating the two actions is exactly parallel. The symbol used is *ro*, and the results under that head are derived from the difference between the numbers of right and wrong answers.

In the cases of *X*, *Y*, *Z*, and *Z'* the action consisted in either aiming a rifle or pointing at the observers. In place of the *ew* criterion, it was necessary to use here the right-plus-wrong answers, since east and west did not enter the question. In saying that he saw the man point, or aim the rifle, the observer states, although not specifically, that he saw the movement; and this is irrespective of whether he is right or wrong as to its differentiation. The symbol *p* refers to this criterion; while the right-minus-wrong number of answers as to aiming or pointing is the argument in the results under the head *ro*.

The percentages are always based on the total possibilities of the case. Under *S* this will be the total number of experiments; but under *ew*, *ro*, and *p* the total possibilities will be the number of times the man was seen. Discrimination is not possible unless the object is, in the first place, "picked up" and the glass and the eyes fairly trained upon it. The method of computation of the percentages will be treated in detail later on.

In Tables XI and XII the results are grouped by stations (*A*, *B*, *C*, etc.); in Table XI, also, by calendar days (March 18th, 19th, 20th and 26th), and in Table XII by days of practice (I, II, III, and IV). From these two tables the mean percentages were

TABLE XIII.

Weighted Mean Percentages of Correct Observation, Day by Day, for all Objects Except E. (The Values Under p, Tables XI and XII, have Been Treated like the ew Values and are Included Here.)

		March			
		18	19	20	26
S	Binocular	55.8	80.0	79.8	80.6
	Monocular	49.7	75.2	77.6	78.4
	Difference	6.1	4.8	2.2	2.2
ew	Binocular	46.7	54.7	57.9	51.0
	Monocular	36.4	46.5	50.9	43.1
	Difference	10.3	8.2	7.0	7.9
ro	Binocular	34.7	44.3	48.8	47.7
	Monocular	26.9	33.8	43.0	36.7
	Difference	7.8	10.5	5.8	11.0

		Day of practice			
		I	II	III	IV
S	Binocular	58.8	80.2	81.8	81.6
	Monocular	52.4	77.0	80.6	77.8
	Difference	6.4	3.2	1.2	3.8
ew	Binocular	44.9	55.5	60.2	50.9
	Monocular	38.0	47.1	53.4	42.3
	Difference	6.9	8.4	6.8	8.6
ro	Binocular	31.6	47.7	51.2	49.0
	Monocular	27.7	36.7	43.6	36.2
	Difference	3.9	11.0	7.6	12.8

		For all days	All except I
S	Binocular	74.70 ± 0.06	81.1
	Monocular	70.93 ± 0.07	78.4
	Difference	3.77	2.7
ew	Binocular	53.45 ± 0.05	55.8
	Monocular	45.55 ± 0.14	47.8
	Difference	7.90	8.0
ro	Binocular	45.18 ± 0.17	49.2
	Monocular	36.34 ± 0.07	38.9
	Difference	8.84	10.3

averaged for each day and the averages are given in Table XIII. These averages are plotted in Fig. 12. In computing the averages, Station *E* was omitted, for the reasons that the conditions of vision (a moving object) were not comparable to those of the other stations, and since *E* simply walked up and down with no action comparable to raising an arm or aiming a rifle, there were no data at all comparable to those under the heads *ew* and *p*. Casual examination of the results will show at once that the results in the case of *E* support the ultimate conclusions more strongly than the other results.

The weights assigned to the various stations and used in computing the averages in Table XIII were derived from the total numbers of experiments for all four days on the respective stations, Tables XI and XII, and from the similar total of the numbers of times the man was reported seen on all four days at the respective station, under the head *S*. They are, in all cases, computed from these totals for the four days in a manner similar to that in which the base for an individual percentage would be found. This will be clear if we bear in mind how the percentages in the tables were derived. To illustrate, a block from Table XI, *A*, under Monocular, March 19th, is repeated here with additions in parentheses

		Monocular	
	S	*ew*	*ro*
Experiments	176	176	132
Results	163	114	75
Per cent.	(92.6)	(64.8)	(56.8)
Percentages	92.6	70.0	61.3

to show the method of computation. The percentages in parentheses are simply each "result" on its corresponding "experiments" as a base. The final ones for *ew* and *ro* are the ones above, recomputed on the *S*-percentage, 92.6 as a base. For these final percentages as they appear in the table the bases are, therefore, respectively, 176, 163, and $163 \times \frac{132}{176}$. In just the same way the weights for *S*, *ew*, and *ro* are here, respectively, as 631, 568.5, and $568.5 \times \frac{587}{631}$. The number 568.5 is here the mean of the two numerical results under the two *S*'s for monocular and binocular, and was used in computing the weights for both alike. The weights for *A*, *B*, *C*, etc., were reduced to such a scale that the *F* weight (number of experiments = 727) should be 1.00. The

others, to lessen the amount of computation necessary to correct an error, were so scaled that the number 714 should correspond to weight unity. The weights used are:

Station	S	Weight ew	ro
A	0.87	0.77	0.72
B	.86	.30	.30
C	.93	.83	.83
D	.88	.69	.69
F	1.00	.79	.79
G	.81	.52	.52
H	.88	.64	.64
X	.88	.58	.58
Y	.88	.51	.51
Z	.50	.42	.42
Z'	.44	.25	.25

The final results for all days, Table XIII, were obtained from the two sets of day averages just described, by similarly determining the two appropriate sets of day weights and applying them. The figures added after the ± sign indicate how the two averages diverged from their mean in each case. These differences are due to small discrepancies in weighting, and are too small to affect the conclusions in any essential way. The last column of figures in Table XIII gives the results, omitting each observer's first day's results from the computation. It consists, therefore, of the appropriately weighted averages for Days II, III, and IV.

In connection with Tables XI, XII, and XIII, a brief description of the weather during each of the four experimental periods is appended.

March 18, 1918, 2 P.M. to 5 P.M.—Sky, 10/10 clear, bright sun, some haze and dust. Temperature moderate.

March 19th, 2 P.M. to 4.30 P.M.—Sky 8/10 cumulus and cirro-cumulus clouds. Gentle breeze, S.S.E., faint to bright sun, haze and dust in the distance. Air clear for sound. Haze and dust increasing during the course of the afternoon. At 4.18 P.M. the sun went behind a thick cloud. Temperature moderate.

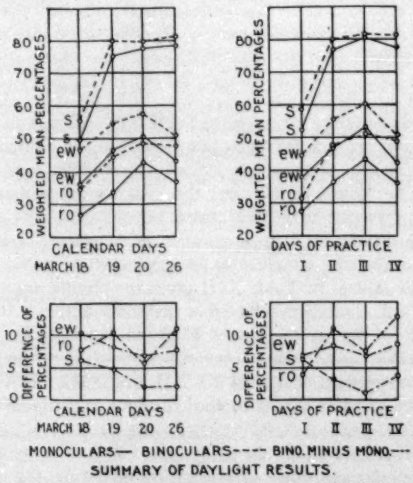
March 20th, 2 P.M. to 4.30 P.M.—Sky 8/10 cirro-cumulus and cirro-stratus clouds, faint sun. More haze than last. Sounds very plain, gentle east wind, comfortable temperature, slight heat shimmer. Increasing cloudiness.

March 26th, 2 P.M. to 4.30 P.M.—At 2 P.M., 9/10 cumulus

clouds, sun through rifts occasionally; at 2.20 P.M., 5/10 clear; at 3.30 P.M., 9/10; at 3.45 P.M., completely clear, sun still well up. Strong N.W. wind, very cold during whole time.

Discussion of the General Daylight Results.—Table XIII and Fig. 12 leave very little to be said, at least as to the fact that in the present test the binocular ran very consistently ahead of the monocular. There is a difference, however, in the way the two glasses compare as to the different criteria of the test. Under the

FIG 12.



MONOCULARS— BINOCULARS---- BINO. MINUS MONO.---

SUMMARY OF DAYLIGHT RESULTS.

head *S*, it will be noted, the differences are smaller, and also they tend, in a slight measure, perhaps, to decrease. The mode of vision upon which the results under *S* depend is quite a different one from that underlying the criteria of *ew* and *ro*. In the first case the result will depend primarily on a diligent watching of the various parts of the field and mostly, if not exclusively, upon the activity of the eccentric portions of the retina. It is essentially a process of discovery, and will be modified by many circumstances of attention as well as by the absolute ability to see. Following it, the process of orientation takes place, in which the axis of the

glass is brought into alignment and the eye adjusted for direct vision. Detailed examination of the object then takes place, during which the information is gained which goes to make the results stated under *ew* and *ro*.

How these two modes of vision behave, with respect to the use of the glass and with respect to practice, is a question which it was hoped these results would answer more definitely than they do. Where the monocular shows relative improvement with practice, as it here does, in the matter of first locating the test objects (see *S*, lower right-hand plot, Fig. 12), it is a question for further work to answer whether that relative improvement will go on to the point of equality.

As to the discrimination of details in the test object, the result is quite the other way. Here the binocular shows relative improvement (*ew* and *ro*, same plot). If the observers had previously had preponderant experience with the monocular this would not offer difficulties. The presumption is, if anything, the other way, and the relative improvement of the results obtained with the binocular, in the distinguishing of detail, is hard to interpret otherwise than as evidence of intrinsic superiority of that type of glass for that purpose under conditions such as those of this test.

The extent of the difference for Station *E* is 70 observations of the man out of 684 possibilities. This applies to criterion *S*, the *ew* being absent in this case, and the results under *ro* insignificant. This difference amounts to 10.2 per cent. as against a similar difference of 3.8 per cent. for all other stations (see last section of Table XIII).

It will be recalled that in Part I of this report it was found that all three of the observers had unequal vision in the two eyes, and that binocular vision through a binocular glass was not better than monocular vision with the better eye through the corresponding limb of the same glass. Where it showed a slight superiority in point of the frequency of right answers this was offset by a longer time consumed in observation. Indeed in one case the admission of the inferior eye caused a falling off of vision as a whole, binocular vision giving results inferior, both in point of frequency and time consumed, to those obtained monocularly with the better eye.

However, if we take the mean of the two monocular results in these cases, this mean falls very definitely below the binocular result. This perhaps explains the discrepancy between the conclusions of Part I and this part of the report. If (as is to be assumed, almost as a fact) the observers in this work had unequal vision in the two eyes; and if they either did not know which was the better eye, or used both equally in the monocular work, the comparisons drawn would amount to comparison of the binocular result with the mean of the two hypothetical monocular results. The actual comparison of mean monocular with binocular results, made from the results of Part I of this report, would lead to differences in the same direction and of about the same order of magnitude as those found in this part.

(2) THE TWILIGHT TESTS.

The twilight results were obtained exactly as the foregoing, except that the experimental runs were conducted late in the day and while darkness was coming on. Each observer used one type of glass for the entire day's run, using the opposite type on the second day. On March 22nd the program began at 6 P.M., and on March 25th at 5.45 P.M. As soon as the more distant men (*A* to *H*) became difficult to see, as shown by the results, the nearer ones (*X*, *Y*, and *Z*) were furnished with special schedules, so that one or another of the latter were exposed every ninety seconds from then on. This change in program took place at 6.36 P.M. and 6.34½ P.M. on the respective days, the times being indicated in Table XIV by the horizontal lines drawn across the appropriate columns. Nine and fifteen minutes later, on the respective days, the last observations of any of these men were made, the darkness having become too profound in the interval for further observation, even at these short distances. It will be noticed from the table, however, that on March 22nd the failure of the daylight program took place somewhat before the time mentioned, at about 6.24 P.M., making the twilight interval for that day 21 minutes.

This fact serves to emphasize the rapidity with which the daylight fails, for while during the day there are enormous variations in the intensity of light, vision is affected less by these than it is by the presence or absence of shadows. Yet from the last moment that it was practicable to distinguish a man at (say) 1500 yards

Twilight Results.

March 22																			March 25														
Station	Monocular 24 Observers S	ew	ro	Binocular 24 Observers S	ew	ro	Difference S	ew	ro	Weighted Monocular S	Results Binocular S	Time	Station	Monocular 23 Observers S	ew	ro	Binocular 23 Observers S	ew	ro	Difference S	ew	ro	Weighted Monocular S	Results Binocular S
												5.51	D	12	4	8	10	7	7	−2	3	−1	15.0	12.5
												.52½	G	8	3	2	8	0	2	0	−3	0	11.4	11.4
												.54	F	19	13	17	23	9	18	4	−4	1	23.8	28.8
												.55½	J	1	0	0	1	0	0	0	0	0	2.8	2.8
												.57	D	21	14	18	22	12	20	1	−2	2	26.3	27.5
												.58½	A	17	3	11	20	9	14	3	6	3	18.9	22.2
D	15	7	9	19	2	12	4	5	3	18.8	23.8	6.00	F	13	4	8	13	6	9	0	2	1	16.2	16.2
B	0	0	0	0	0	0	0	0	0	0.0	0.0	.01½	X	18	2	−4	21	3	−1	3	1	3	19.9	23.2
E	0	0		1	0		1	0		0.0	3.9	.03	X	18	2	2	21	3	3	3	1	1	20.9	31.4
H	6	0	0	4	0	0	−2	0	0	8.0	5.4	.04½	D	21	4	16	23	16	22	2	12	6	26.3	28.8
G	0	0	0	2	0	0	2	0	0	0.0	2.9	.06	Y	17	4	4	17	4	6	0	0	2	28.8	28.8
Z	23	7	7	23	7	13	0	0	6	27.1	27.1	.07½	G	11	−2	2	12	4	6	1	6	4	15.7	17.1
D	24	−5	7	24	3	15	0	8	7	30.1	30.1	.09	H	20	1	7	19	10	11	−1	9	4	26.8	25.5
B	0	0	0	0	0	0	0	0	0	0.0	0.0	.10½	Z	3	1	1	7	0	0	4	−1	−1	4.5	10.5
F	18	−6	12	17	0	10	−1	6	−2	22.5	21.2	.12	B	3	0	0	2	0	0	−1	0	0	8.5	5.6
G	0	0	0	0	0	0	0	0	0	0.0	0.0	.13½	D	22	−2	10	22	3	17	0	5	7	27.6	27.6
Y	16	0	2	13	1	1	−3	1	−1	27.1	22.0	6.15	X	22	0	0	19	0	2	−3	0	2	32.9	28.4
Z	2	0	0	2	0	0	0	0	0	3.0	3.0	.16½	H	19	0	−1	21	10	6	3	10	7	25.5	28.2
X	19	4	4	17	2	2	−2	−2	−2	28.4	25.4	.18	Z	22	9	15	21	14	20	−1	5	5	25.9	24.7
C	0	0	0	0	0	0	0	0	0	0.0	0.0	.19½	Y	12	0	2	13	6	6	1	6	4	29.4	22.0
A	14	0	0	18	2	2	4	2	2	15.5	20.0	.21	C	23	1	1	24	2	1	0	1	0	25.4	25.4
D	21	1	7	22	5	7	1	4	0	26.3	27.6	.22½	X	23	−4	6	20	7	11	−3	11	5	34.3	29.9
B	0	0	0	1	0	0	1	0	0	0.0	2.8	.24	A	23	6	6	23	13	13	0	7	7	25.5	25.5
Z	1	0	0	0	0	0	−1	0	0	1.5	0.0	.25½	E	0		0	0		0	0		0	0.0	0.0
H	0	0	0	0	0	0	0	0	0	0.0	0.0	.27	B	0	0	0	0	0	0	0	0	0	0.0	0.0
G	0	0	0	0	0	0	0	0	0	0.0	0.0	.28½	Z	22	0	2	22	0	6	0	0	4	25.9	25.9
C	0	0	0	0	0	0	0	0	0	0.0	0.0	6.30	A	18	0	4	20	−1	7	2	−1	3	20.0	22.2
Y	13	0	0	12	0	0	−1	0	0	22.0	20.4	.31½	Y	5	0	0	5	1	1	0	1	1	8.5	8.5
A	1	0	0	1	0	0	0	0	0	1.1	1.1	.33	Z	5	0	0	8	0	0	3	0	0	7.5	12.0
H	0	0	0	0	0	0	0	0	0	0.0	0.0	.34½	X	14	0	0	14	0	2	0	0	2	20.9	20.9
X	11	0	0	12	0	0	1	0	0	16.4	17.9	.36	Y	9	0	0	10	1	1	1	1	1	15.2	20.9
												"	(E)	0	0	0	1	0	0	1	0	0		
Z	3	0	0	4	0	0	1	0	0	3.5	4.7	.37½	X	17	0	0	11	−1	1	−6	−1	1	41.6	37.6
												"	(F)	13	1	1	17	5	8	4	4	7		
X	3	0	0	5	0	0	2	0	0	4.5	7.5	.39	X	15	1	1	18	1	1	3	0	0	25.1	32.3
												"	(H)	2	0	0	4	0	0	2	0	0		
Y	3	0	0	3	0	0	0	0	0	5.1	5.1	.40½	Z	21	0	0	20	3	3	−1	3	3	24.7	23.6
Z	2	0	0	3	0	0	1	0	0	2.4	3.5	.42	Y	14	0	0	14	0	0	0	0	0	24.8	24.8
												"	(C)	1	0	0	1	0	0	0	0	0		
Y	0	0	0	2	0	0	2	0	0	0.0	3.4	.43½	Y	4	0	0	6	0	0	2	0	0	6.8	10.2
X	2	0	0	2	0	0	0	0	0	3.0	3.0	.45	X	3	0	0	5	0	0	2	0	0	4.5	7.5
												.46½	Z	1	0	0	1	0	0	0	0	0	1.2	1.2
												.48	Z	0	0	0	0	0	0	0	0	0	0.0	0.0
												.49½	Y	1	0	0	0	0	0	1	0	0	1.7	0.0

Explanation.

S—the number of observers who recorded seeing the man at the designated station.
ew—the number of observers who correctly recorded the direction of the action.
ro—the number of observers who correctly differentiated the action.
For explanation of "weighted results" see page 353.

there remained only twenty minutes or so during which a man could be distinguished at 400 to 600 yards. Consequently, the results, extending as they do over only these short periods of time, do not show anything that is on the whole conclusive. Results to be conclusive would have to extend over longer periods of time, as, for example, on clear nights at a definite phase of the moon, and would require a specially arranged program suited to the low visibility under such conditions, as will be evident on inspecting the parts of the table corresponding to the critical intervals.

Examination of these parts of the table shows that the man in the field was detected, in many cases, by only a very few, often by none, of the 24 or 23 observers represented in the column. The percentage was extremely low, and percentages falling very near to either 0 or 100 are not, as a rule, reliable for the purpose of drawing conclusions, especially when they fluctuate as these do.

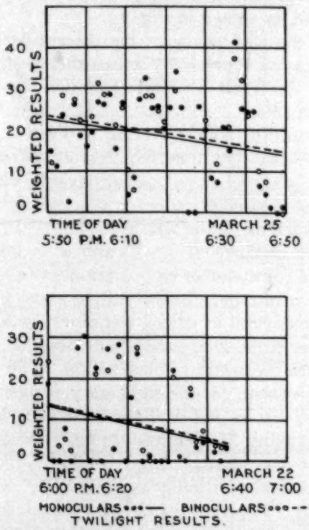
For reasons such as the above the results that were obtained March 22nd and 25th are given in Table XIV exactly as they were first summarized from the observers' original records. They represent in the aggregate 1¾ hours of work, of which, as was stated above, perhaps 35 minutes represent conditions pertinent to the point under investigation; while in the case of the daylight results just discussed the total time of work done by practically the same group of observers was 10 hours under favorable conditions.

The data were examined to see whether there was a noticeable difference in the behavior of the two types of glass as darkness approached. For this purpose only the numbers under *S* were employed, and each was assigned a weight, based upon the daylight observations, such that if the weighted number of times that the man at each station was seen were plotted as ordinates and the time of day as abscissæ, the resulting plot would approximate a horizontal straight line. The weight used for each station is the reciprocal of the average number of times, expressed in per cent., that the man was seen by both monoculars and binoculars on all four days of daylight observation. Those weights applied to data taken in waning light would naturally, when plotted, produce a line sloping downward as time progresses.

The weighted results are included in Table XIV and plotted

in Fig. 13. As was to be expected, the points scatter badly, so that any deduction based upon them should be substantiated by other facts before being considered final. The lines plotted were determined by the method of least squares on the assumption that

FIG 13.



the curve of decline is a straight line. The initial and final points of these lines yield the following information:

	March 22		March 25	
	Initial	Final	Initial	Final
Monocular	13.87	4.30	23.38	14.50
Binocular	13.51	3.67	22.46	13.70
Difference	0.36	0.63	0.92	0.80
$\frac{\text{Difference}}{\text{Monocular}} \times 100$	2.68	17.2	3.94	5.84

The last line of this table measures the advantage of the binocular over the monocular, and shows that this advantage increases as the light becomes dim; a result wholly in accord with the findings

of Part II of this report. From Table XIII the advantage, computed into comparable form, for the daylight results of Days II, III, and IV is $\frac{2.7}{78.4} \times 100 = 3.44$ per cent., a result quite in agreement with the two initial values just given, 2.68 and 3.94 per cent., considering the paucity and scattering of the data upon which the latter depend, as shown in Fig. 13.

In view of the inadequacy of the present data, little weight is to be given to the conclusions drawn therefrom. They in no way contradict the results of Part II of this report, but tend to confirm those results.

It is interesting to note, referring to Part II, that vision at the twilight intensity then used required an object 15.6 times as large (in terms of visual angle) as for daylight vision. We may roughly estimate a similar ratio for the two light-extremes involved in the work at Camp Meade.

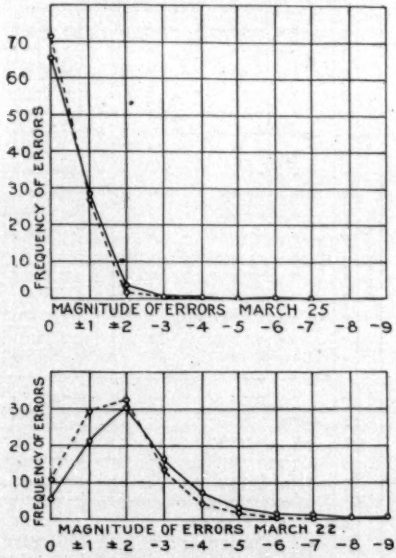
The average distance of *X*, *Y*, and *Z* is 487 yards. The average distance for the other eight stations is 1424 yards. Now, from the plots of the data in the earlier parts of this report it appears that a reduction in size of test object by one of the steps used, about 9 per cent., brings about a decrease of something like 25 per cent. in the frequency of observation. The frequency may be taken at 75 per cent. for the eight stations mentioned, and the estimate follows that in full daylight these men would be at the border of invisibility if removed to an average distance of 1424×1.09, or 1845 yards. That is, they would then be of about the same order of visibility as *X*, *Y*, and *Z* were at the close of the day's run. The ratio of the two visual angles would be 1/487 to 1/1845, or 3.8, as compared with 15.6, the similar figure derived from the laboratory results. That is to say, the illumination at the close of the day's twilight run in the open was such as to permit three times the visibility (measured in visual angle) obtained with the light previously used in the laboratory. This is, perhaps, another reason why the present results do not show a stronger twilight effect than they do in favor of the binocular.

(3) THE COUNTING TESTS.

The counting tests were conducted March 22nd, from 4.55 P.M. to 5.45 P.M., and March 25th, from 4.45 P.M. to 5.45 P.M., in each case immediately preceding the twilight test of that day. The program required all of the eleven men in the

field to be at a designated station, formed in an irregular line and concealed by crouching behind a slight rise of ground or, in the case of Station *H*, behind a brush concealment. At a word from their sergeant a prearranged variable number of them, from 7 to 11, rose to their full height, remained standing for 10 seconds and dropped out of sight again at a second command. The observers

FIG 14.



were informed in advance of the place to look, and were warned a few seconds before the men appeared.

This program involved Stations *B*, *D*, and *H* only. At each one there were ten exposures as described. In a short interval between the fifth and sixth the observers exchanged glasses, monocular for binocular, and continued with them until they re-exchanged after the fifth at the next station. Those who on

TABLE XV.

Counting Tests.

	Station *B*										Station *D*										Station *H*										Totals
											March 22, 1918																				
Men exposed	7	11	9	8	10		8	9	10	11	7	11	7	9	10	8		9	10	8	7	11	8	10	7	9	11		10	7	8	11	9	
												Monoculars																					
Correct counts	0	0	0	0	3		2	1	0	0	1	1	3	1	2	3		0	1	2	1	0	0	0	7	7	0		0	4	1	0	0	40
Errors +2	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	1
+1	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	3	.		.	1	.	.	.	6
−1	1	.	3	3	10		16	2	2	5	23	1	4	4	4	2		7	8	4	1	3	3	2	5	6	4		.	8	6	.	10	147
−2	8	9	14	10	9		5	7	11	14	.	3	2	7	11	9		4	10	10	10	11	4	5	4	3	5		5	6	3	9	5	219
−3	5	7	3	7	.		.	8	8	5	.	1	4	3	3	4		5	2	6	5	5	5	4	3	1	4		8	2	4	4	4	120
−4	1	3	.	2	1		.	5	2	.	.	1	4	1	1	2		2	.	.	1	.	2	5	4	1	4		4	1	4	3	3	53
−5	1	.	.	1	.		.	.	1	.	.	.	.	2	2	2		3	.	.	.	.	2	1	.	.	1		1	.	3	4	.	23
−6	.	.	.	.	.		.	.	.	.	.	.	1	1	.	.		.	.	.	.	.	.	1	3	.	.	1		2	.	1	1	.	11
−7	.	.	.	.	.		.	.	.	.	.	.	.	1	.	.		.	1	1	.	.	.	.	1	.	.	1		.	2	.	1	1	9
−8	.	.	.	.	.		.	.	.	.	.	.	.	.	1	.		.	.	.	.	.	.	.	.	.	.	1		.	.	.	.	.	2
−9	.	1	.	.	.		.	.	.	.	.	.	.	.	.	.		.	.	.	.	1	.	.	.	.	.		.	.	.	1	.	4
Failures	8	4	2	1	1		.	1	.	.	.	17	9	4	.	2		2	2	1	1	1	5	5	4	3	3		3	2	2	1	1	85
Number of Observers	(24)						(24)					(24)						(24)					(24)						(24)					720
												Binoculars																					
Correct counts	0	0	3	1	2		4	2	1	2	1	1	3	4	3	5		4	6	3	5	3	0	0	9	10	0		0	5	1	0	0	78
Errors +1	.	.	.	.	1		.	1	.	.	.	.	.	.	.	.		.	.	1	1	.	.	1	.	3	.		.	1	.	.	.	9
−1	1	5	4	3	14		18	2	2	5	23	2	9	3	8	2		3	13	8	6	7	8	3	12	6	6		1	9	8	3	9	203
−2	12	13	10	10	7		1	5	12	13	.	2	2	6	8	10		9	3	6	9	10	9	12	2	2	10		11	4	7	11	7	235
−3	7	5	1	3	.		.	10	7	3	.	2	3	7	3	4		4	.	5	2	4	5	7	.	.	4		5	1	4	2	1	99
−4	2	.	.	1	.		.	3	1	.	.	1	.	2	1	.		1	1	.	.	.	1	1	.	.	2	2		4	.	1	2	5	31
−5	.	.	.	.	.		.	.	.	.	.	1	.	.	.	2		2	1	1	1	.	1	1	.	.	.	1		.	.	.	1	1	12
−6	.	.	.	.	.		.	.	.	1	.	1	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	3
−7	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.		1	.	.	.	.	.	.	.	.	.	1		.	.	.	1	.	3
Failures	2	1	.	.	.		1	1	1	.	.	14	7	2	1	1		.	.	.	.	.	.	.	1	.	1	.		3	4	3	3	1	47
Number of Observers	(24)						(24)					(24)						(24)					(24)						(24)					720

March 25, 1918

Men exposed	7 11 8 10 9	10 11 8 7 9	8 7 9 10 11	11 8 9 7 10	10 11 7 8 10	10 7 11 9 9	
Monoculars							
Correct counts	16 11 16 17 14	6 9 19 19 16	13 11 5 14 17	17 19 15 17 18	13 14 20 18 10	11 12 11 20 10	428
Errors +2	. . . . .	. . . . .	. 1 . . .	. . . . .	. . . . .	. . . . .	1
+1	. . 1 1 3 2	1 1 1 2 1	5 3 1 1 .	. . 2 1 1 2	1 . 1 . 1	1 1 . . 3 3	40
−1	4 7 3 . . 4	9 8 2 1 5	3 6 6 4 3	3 . . 3 3 1	7 8 1 4 11	9 10 12 . . 10	147
−2	. 1	1 4 . . .	2 2 6 3 3	1	1	2	26
−3	. . . . .	2	. . 2 . .	. . 1 . . .	. . . . .	. . . . .	5
−4	. . . . .	1	. . . 1 .	. . . . .	. . . . .	. . . . .	2
−5	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .	0
−6	. . . . .	. . . . .	. . . . .	. . . 1 .	. . . . .	. . . . .	1
−7	. . . . .	1	. . . . .	. . . . .	. . . . .	. . . . .	1
Failures	. . . . .	1	. . 3 . .	. . . . .	. . . . .	. . . . .	4
Number of Observers	(20)	(22)	(23)	(21)	(22)	(23)	655
Binoculars							
Correct counts	16 11 18 16 13	15 14 20 14 20	18 18 9 18 21	16 19 15 19 19	11 12 23 13 8	14 14 13 17 10	464
Errors +2	. . . . .	. . . . .	. 1 . . .	. . . . .	. . . . .	. . . . .	1
+1	. 1 2 2 4	1 . . . 4	2 2 . . .	2 2 1 1 2	2 . . . 3	2 1 . . 3 3	40
−1	3 9 2 3 4	3 6 . . 1	1 . 10 3 .	4 2 7 3 2	9 10 . 9 12	6 7 9 2 9	136
−2	1 . . 1 1	1 . . . 1	. . . . .	1	1 1 . 1 .	. . . . .	9
−3	. . . . .	. . . . .	. . 2 . .	. . . . .	. . . . .	. . . . .	2
Failures	2 1 . . .	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .	3
Number of Observers	(22)	(20)	(21)	(23)	(23)	(22)	655

the first day began with one type of glass began on the second day with the other.

The results are summarized in Table XV. In some cases the number was overcounted by 1, rarely by 2. Such cases are indicated in the table, but in the plot (Fig. 14) they are classed with the misses, irrespective of algebraic sign.

On the first day visibility was low on account of haze. This circumstance, coupled with the inexperience of the observers in this particular problem, made a characteristic difference in the outcome. It will be noted that the correct counts are few, 10.8 per cent. and 5.6 per cent. of the total with binoculars and monoculars, respectively, while on the second day the corresponding results are large, 70.8 per cent. and 65.3 per cent. In other words, most of the results of the first day involve errors. The upper plot will show, however, that apart from a 5.3 per cent. advantage in correct counts the binocular has to its advantage a lower number of large errors. Unless this were pointed out, the plot might be misleading, since it shows a conspicuously larger number of small errors for the binocular. This is simply the natural effect of the other circumstance. The binocular counts deviate less from correctness than the monocular. This is brought out by the following taken from Table XV:

	March 22		March 25	
	Monoc.	Binoc.	Monoc.	Binoc.
Experiments	720	720	655	655
Correct answers	40	78	428	464
Failures	85	47	4	3
Miscounts	595	595	223	188
Aggregate error in miscounts	1,461	1,202	277	202

The "aggregate error" does not here include the errors implied in the "failures," which are listed in the line above "miscounts."

The following weather notes are to be considered in connection with the above:

March 22nd, 4.55 P.M.—Light failing, fairly dense haze. 5.15 P.M. to 5.30 P.M.—Sun, well up in the sky, appeared red, not orange, and was on the point of going behind a cloud bank. 5.31 P.M. to 5.35 P.M.—Haze very deep and hard to penetrate with glasses.

March 25th.—Clear, except for occasional blowing sand. High wind, W. by NW., very cold, stiffening fingers. Very good seeing.

(4) THE TIMING TESTS.

In all of the preceding work the original group of officers, with such absences and substitutions as were unavoidable, acted as observers. In the timing work, about to be described, the observers were the group of men who had previously acted as visual objects in the field. These were ten privates and one first sergeant. The last, and seven others were men of some academic training, awaiting the opening of the Ordnance School; the other three, and one extra man on the second day, were privates detailed from the ranks of the Ordnance Company for this work. They were, on the whole, especially the first eight, men of intelligence and ambition. The work was done in the forenoons of March 22nd and 23rd.

On the first of these days the weather was warm and the air somewhat hazy. On March 23rd it was cold and exceptionally clear, with a tendency for the fingers to stiffen and so delay the observer.

In the test with the binocular the subject started with the glass in its case and the lid fastened. In the monocular tests the glass was initially in his breast pocket with the flap buttoned. Before the test was begun each observer adjusted his glass, including in the case of the binocular the clamping of the stop for limiting the interpupillary distance, and placed it in his pocket or in its case without disturbing the adjustments more than necessary. The test object consisted of two short, parallel black strips, ½ by 1½ inches, separated by an interval of ½ inch, and placed in the centre of a square white board, which was held by one of the men with the bars vertical or horizontal, according to a predetermined chance schedule, and at such a distance that the direction of the bars was not to be distinguished without the aid of the glass. This distance was about 160 yards.

At a given signal the subject started to get out the glass and as soon as he was able to see the object he announced the direction of the bars. Two stop-watches were used. One was started at the initial signal, the second when the subject had the glass at his eye, and both were stopped the instant he announced the position of the object. If he fumbled the glass, as happened especially on the second (cold) day, the experiment was thrown out and repeated; the same was done if, as occasionally happened, he announced the wrong position of the test object.

As the experiments were conducted there were two results from each. The watch first started gave the whole time required to get out the glass and to get good vision of the object; the second gave the time to get good vision from the instant the glass was in position at the eye or eyes. This last, for want of a better name, is here designated the "pick-up" time. The difference between the two will be the delay in getting the glass from its carrying-place to the eye. The results follow:

	March 22, 1918		
	Whole time	Delay	Pick-up
Binocular	6.87 ± 0.20	(4.25 ± 0.22)	2.62 ± 0.09
Monocular	5.53 ± 0.24	(2.59 ± 0.29)	2.94 ± 0.17
Difference	1.34 ± 0.31	1.96 ± 0.36	−0.32 ± 0.19
	March 23, 1918		
Binocular	6.94 ± 0.24	(4.60 ± 0.25)	2.34 ± 0.08
Monocular	5.85 ± 0.20	(3.07 ± 0.23)	2.78 ± 0.12
Difference	1.09 ± 0.31	1.53 ± 0.34	−0.44 ± 0.14

In the first day's work the figures are each the result of 22 experiments, in the second 24. The probable errors are added.

It will be seen that the delay is greater for the binocular by about 1.5 to 2.0 seconds, with a very small degree of uncertainty. These differences, of course, apply to the conditions of the experiment—the binocular carried in its case, slung over the shoulder with the lid fastened, and the monocular in the buttoned breast pocket. It is to be added that the binocular cases were new, and consequently stiffer and harder to handle than in average practice.

The difference in the pick-up time is in favor of the binocular. It is not large, but its probable error is sufficiently small to make it appear far more like a true experimental result than like an accident. The possibility remains, nevertheless, that this difference might disappear with adequate practice. Against this must be placed the fact that the difference is here greater on the second day than on the first. If we exclude the results of the twelfth man who came to this experiment for the first time on the second day, we get for the pick-up times: Binocular, 2.30 seconds; monoc-

ular, 2.83 seconds; difference in favor of the binocular, 0.53 seconds. As far as can be said from these results, then, this difference grows with practice rather than the contrary.

(5) OPINIONS OF THE OFFICER-OBSERVERS.

At the close of the last day's work of the officers who acted as observers in the first three tests detailed here, they were asked to state their personal preference as to the type of glass and to give their reasons for the choice.

Expressions were obtained in this way from 43 men, all of whom but one chose the binocular. The reasons stated were analyzed as follows:

GROUP I. Statements made as favoring the binocular:			
1. "Easier on the eyes" unqualified	20	*HS*	
"For lengthy observation" ..... 3 "Trouble with open eye" 2	5	*S*	
2. "Objects can be seen more 'clearly,' 'distinctly,' or 'with better detail'"	17	*CS*	
3. "Movements more clearly defined"	2	*CS*	
4. Superior in "blurry lights," on "dark days" or "in twilight"	4	*CS*	
5. Easier to "pick up" an object	6	*CS*	
6. "Better for close-up work" and "Better view of landscape"	2	*CS*	
7. "Can change from point to point quicker"	1	*S*	
8. Easier to get "steady vision," "hold steady" or "hold on object"	8	*S*	
9. "Quicker adjustment"	2	*Q*	
10. "Better illumination"	2	*PQ*	
11. "Field of view larger"	9	*X*	
12. "Brings objects nearer," "image larger" or "more powerful"	3	*X*	
13. "Natural consequence that a person can see better with two eyes"	1	*P*	
14. "Believe I can do better work"	2	*S*	
15. "Blurring with monocular"	1	*S*	
Total	85		85
GROUP II. Statements made as favoring the monocular:			
1. "Better on monocular with practice"	3	*S*	
2. "No reason why it could not be used with success after I get used to it" or "for all but the finest work"	6	*S*	
3. "Quicker pick-up"	1	*S*	

4. "Lightness (and cost)"	1	*S*	
5. "Adjustment quicker and simpler"	2	*S*	
6. "Easier to handle"	1	*S*	
Total	14		14
GROUP III. Statements favoring neither glass:			
1. Seeing the same with both	8	*S*	
Total	8		8
Grand Total			107

The opinion of the writers as to the validity of these reasons is indicated by the letters following the numbers attached to each sub-group above, the key to these following:

C – Confirmed by the conclusions of this report or other facts.
H – Possibly hearsay.
P – Prejudgment.
Q – Question as to meaning of statement.
S – Statement of man's opinion as asked for.
X – Contrary to physical facts.

While there are 85 points, out of a total of 107, expressed in favor of the binocular, it is noteworthy that the statements in favor of the monocular and the indifferent statements are not subject to such dubious criticisms as are here symbolized by the letters *H*, *P*, *Q*, and *X*.

While it cannot be denied that an expression in favor, say, of the binocular, however clumsily and erroneously stated, might be motivated at bottom by the author's actual experience with the instrument, yet the common tendency is strong to read into that experience a mass of ostensibly related material—opinions heard which may or may not be well founded, and which may in either case be the basis of prejudgment; inferences from real or supposed facts otherwise known, and so on. For example, near the close of the work on one of the twilight runs, one of the men in the distant field stopped, on his way in, to talk with the man at *B*. While there he struck a match. While a number of the observers stated that at a certain minute "*B* lit a cigarette," there was but one who reported exactly what he saw, which was "a light at *B*."

The absence of questionable matter among the expressions in Groups II and III, and its presence in Group I above, would indicate that there does not exist any body of preconception in favor

of the monocular, while in favor of the binocular such preconception does exist. The exact results of this report bear out the opinions in their main tendency; nevertheless, it is clear that opinions not so supported can be credited only with the greatest caution. Otherwise, of course, the present work would not have been undertaken.

SUMMARY OF CONCLUSIONS.

(1) In daylight under various weather conditions 7174 experiments were conducted in the course of four days with binocular glasses, and simultaneously an equal number with optically identical monoculars. The test objects were men, one at each of eleven points in the field, their distances being various, from 410 to 1850 yards.

Out of the 7174 possible cases the men were detected in 5047 cases with the binoculars and in 4726 with the monoculars. The difference is 321, which is 4.5 per cent. of the total or 6.8 per cent. of the number observed with the monoculars.

One man at 1850 yards, walking just within a wood, was seen with the binocular 211 times, with the monocular 141, out of 684 posibilities in each case. The difference is 70, which is 10.2 per cent. of the total, or 49.7 per cent. of the monocular number.

The other men, at 410 to 1800 yards, were seen in 74.70 and 70.93 per cent. of 6490 cases with the binocular and monocular, respectively. The difference is 3.8 per cent. of the total, or 5.3 per cent. of the monocular result.

(2) The ability correctly to discriminate posture, once the man is localized in the field, is based on the number of times he is seen at all. It is different, according to the criterion of discrimination used.

For the detection of the fact, once the man is seen, that he is either aiming a rifle or extending an arm, the figures show: Monocular, 45.55 per cent.; binocular, 53.45 per cent.; difference, 7.9 per cent. of total men observed, or 17.3 per cent. of monocular result.

For correct discrimination between aiming a rifle and extending an arm, the corresponding figures are: Monocular, 36.34 per cent.; binocular, 45.18 per cent.; difference, 8.84 per cent., or 24.3 per cent. of the monocular result.

(3) How these differences will be affected by practice is indi-

cated in the results—the differences under (1), last paragraph of this summary are largest for the first day of work. Excluding the first day's work of each observer, the differences are 2.7 per cent. and 3.45 per cent., as against the differences 3.8 per cent. and 5.3 per cent. there stated for the four days. After the first day there is possibly still a tendency for the difference to diminish.

On the other hand, the detection and discrimination of posture improves no faster with the monocular than with the binocular as practice goes on; the difference tends to increase rather than to diminish.

(4) Similarly planned experiments carried out at the end of the day in the failing light showed slight increase in these differences as the light wanes. More abundant experiments would be necessary to settle this point conclusively, but the ones at hand tend to confirm the conclusions of Part II of this report as to the advantage of the binocular in light of twilight intensity.

(5) In counting groups of men, from 7 to 11 in number at distances of 1190 to 1800 yards, as compared with the monocular, the binocular showed more correct counts, by 5.2 per cent. to 5.5 per cent. of the total experiments; fewer total failures (by 44.7 per cent. of the monocular failures on one hazy day); and a smaller aggregate error in the remaining counts, by 17.7 per cent. and 27.1 per cent. of the aggregate monocular error for the two days, respectively.

(6) The differences in favor of the binocular, so far summarized, may be due in part to an inequality of the acuteness of vision in the two eyes, in that with the monocular the poorer eye is used alone a part of the time, while with the binocular the good eye is always at work.

(7) Forty-six experiments with each type of glass showed that 1.5 to 2.0 seconds more were consumed in the delay incidental to getting the binocular to the eyes from its carrying-place than were similarly required to get the monocular into action. On the other hand, the binocular, once at the eyes, enabled the user to report on an easily visible test object in 0.32 to 0.44 seconds less time than the monocular. The corresponding times themselves (delay and "pick-up" time), averaged for both glasses, were 3.6 and 2.7 seconds, respectively.

(8) Of the opinions of 43 observers who took part in the bulk of this work, all but 1 were in favor of the binocular. Of the

reasons, in detail, given for the choice, 85 were in favor of the binocular; 14 points of favor were at least admitted for the monocular, and 8 statements were made to the effect that the two afforded equally good vision. Evidence of preconception was abundant in the reasons stated for preferring the binocular and not elsewhere.

PART IV.

SUMMARY AND CONCLUSIONS.

IT remains to discuss the bearings of this work upon the practical question of field-glasses for military use.

A. The fundamental points in physiological optics upon which the problem rests have been discussed in the introduction. They are, as far as can be formulated:

(1) The question of visual acuity;

(2) The perception of brightness (and possibly color) difference;

(3) The twilight effect, *i.e.*, the modifications of these that may be encountered in dim light;

(4) The stereoscopic effect.

B. Aside from these, certain practical considerations enter the problem, some of which, at least, are less easily susceptible of experimental measurement:

(1) The cost and time of production and of maintaining the glass in usable condition; the ease of carrying, etc.;

(2) The comfort, convenience, freedom from fatigue and eye-strain in the use of the glass;

(3) The speed of application and use in the field.

A (1) Field tests with a limited number of observers (Part I of this report) showed, with equal mechanical convenience of using the glass, that the binocular use of the glass at best yielded no better results than monocular use in connection with the observer's better eye. The field tests of Part III do not confirm this, but it must be said that it is an unknown factor whether or not the observers in the latter case invariably used the better eye. Presumably they did not. And further, the mechanical convenience of using the glasses, monocular and binocular, in the latter case was not equalized. In addition, there was a decided difference in the character of the test objects used in Parts I and

III; in the former the object was of minimal size and maximal contrast, while in the latter the size of the objects placed them well above the threshold, but the brightness difference and also the color contrast were, as a rule, small.

(2) Laboratory work (without glasses) has shown that the perception of small brightness differences, *e.g.*, faint shadows, is more acute with two eyes than with one. Again, when the test object is the faintest luminous patch visible in the dark, it is found, when the subject has remained in the dark for some time, that the patch to be seen with one eye must be nearly twice as bright as the same surface just binocularly visible.

(3) The twilight modification of vision, with respect to visual acuity, occurred in the Laboratory (Part II) in the sense of better vision for the binocular, other conditions equalized. The results of the practical test confirm this for the conditions of the test, or at least they wholly fail to contradict it in any way.

(4) The stereoscopic effect plays a distinct, perhaps very important, part in ordinary vision in localizing objects as to distance. Yet it hardly appears that it is of prime importance from the military standpoint. In one case (Part III of the report) the test object at Station *D* was seen against a background much more remote, and afforded a very marked stereoscopic effect. The average results for the experiments on this station, and, for comparison, the averages for all stations from Table XIII are given here:

D, from totals, Table XI or XII

	S	*cw*	*ro*
Binocular	81.7	82.8	71.0
Monocular	78.0	74.5	60.5
Difference	3.7	8.3	10.5

D, weighted as finals, Table XIII

	S	*cw*	*ro*
Binocular	81.06 ± 0.08	81.34 ± 0.31	69.77 ± 0.53
Monocular	77.29 ± 0.01	72.53 ± 0.34	58.18 ± 0.22
Difference	3.77	8.81	11.59

All stations, as in Table XIII

	S	*cw*	*ro*
Binocular	74.70 ± 0.06	53.45 ± 0.05	45.18 ± 0.17
Monocular	70.93 ± 0.07	45.55 ± 0.14	36.34 ± 0.07
Difference	3.77	7.90	8.84

The first figures are the percentages derived from the total numbers under *D*, alike in Tables XI and XII. The second set are the averages of the daily percentages, weighted exactly as the values for all stations, Table XIII. For comparison the final averages for all stations (Table XIII) are here repeated.

It will be seen that the values for *D*, however treated, show the same divergence from the values for all stations. The *S*'s are practically the same, while under *ew* and *ro* the results for Station *D* are somewhat larger than the general averages. The binocular parallax at *D*—computed from the distances 1190 yards (*D*) and 1190+500 (background), taking the distance between the objectives from one of the binoculars used, set for 65 mm. pupillary distance, as actually measured, 4.9 inches or 0.136 yard, and finally, taking the magnification as 6—is 41.8 seconds of arc in the visual field. The station next to *D*, in point of the magnitude of effective parallax, is *A*. Here the distances are 1180 and 1180+67 yards, for the man and the background respectively, and the similarly computed parallax is 7.58 seconds. This last is very near to the lowest limit ever assigned as sufficient for a judgment of depth and agrees well with the informal note on Station *A*: "Not much stereoscopic effect," while the parallax at *D* is abundant. The conclusion would seem to be that the stereoscopic effect is a distinct advantage for binocular discrimination; but at the same time it must also be emphasized that, judging from the data just presented, the advantage of the binoculars is almost certainly due largely to other factors that have not yet received sufficient study in isolation, such as the comparative discrimination of small brightness differences, the detection of motion, and in general the part played by the peripheral retina.

In connection with the work done at Camp Meade, it is to be borne in mind that the differences between the monocular and the binocular results are not, in point of magnitude, of sweeping moment. At the maximum the difference amounts to something not over 12 per cent. of the total experiments. If we take it that 25 per cent. difference in frequency corresponds to 9 per cent. difference in size, the size difference equivalent to 12 per cent. frequency-difference is a trifle less than 4.5 per cent. It is then a safe theoretical conclusion that an increase of 4.5 per cent. in magnification (6.27 instead of 6.00) would offset the relative disadvantage of the monocular in the most unfavorable case. What

has just been said has reference to discrimination, under the headings *ew* and *ro* of Part III of the report. In regard to the effect of practice on these particular modes of vision the results seem to show, as far as they go, that the equalization of practice, up to the fourth and fifth days with the monocular, tends rather to increase than to diminish the difference. How far this would ultimately go remains undetermined.

B. As far as the cost and speed of production, and lightness, are concerned, the advantage is overwhelmingly in favor of the monocular. Perhaps under this general head is the place to mention again the difference of 1.5 to 2.0 seconds found in the time required to get the glass from its carrying-place to the eyes. On the other hand, the comfort of use, involving the relative freedom from eye-strain or fatigue in other respects, would play a part in determining the results of the tests; and it also figures in the opinions of the observers. The results of Part III of the report, under the head *S*, depend upon the number of times a given test object was seen, as compared with the total number of times it might have been seen. This depends obviously, on how continuously and thoroughly the individual observer watches the field. As a matter of course, the effectiveness of his vigilance will be influenced by such considerations as those just mentioned. The fraction of the whole time that he has the glass at his eyes will be reduced by the physical inconvenience of holding the glass in position and by the demands of his eyes and the rest of his body for relief from fatigue. These, again, will tend to diminish by habituation to any particular requirement. With regard to the results under *S*, it appears possible that the binocular-monocular difference actually did diminish in this way to some extent, as practice continued.

This difference itself is in harmony with the difference in the time of "picking up" an object, treated in the fifth section of Part III of the report. The difference was, on the average, something like 0.4 seconds in favor of the binocular, and the differences under *S* are no doubt simply another expression of the same underlying fact.

In the foregoing it has been shown that in the hands of not very highly experienced observers the binocular performs slightly better than the monocular, and that the difference in performance can, for 6-power glasses, be expressed as an effective difference in

magnification of about 4.5 per cent.; *i.e.*, a monocular of magnification 6.27 would show the same performance as a binocular of magnification 6.00. This difference of magnification is evidently not regarded by military authorities as of paramount importance, for 6-power glasses were adopted as standard even though tests on binoculars carried on for two years at Ft. Sill, Oklahoma, clearly indicated a magnification of 8 as the optimum for field artillery work. The adoption of the 6-power glass was presumably the result of a compromise between optical and other considerations. Since the behavior of the two types of glasses is not very different, and since the non-optical factors are largely in favor of the monocular, it appears that in many phases of military work, monoculars of the proper magnification can be used to advantage.

The writers wish to acknowledge the courtesy of the Mayfield Country Club in according them the privilege of the grounds for the purpose of the work discussed in Part I, the generosity of the Warner & Swasey Company for the loan of the two terrestrial telescopes used in Parts I and III, the hearty coöperation of all members of the Board to Test Snipers' Equipment in the work reported in Part III, and the services of Mr. George Hathaway and Mr. Stanley Seidman as observers and technical assistants in Parts I and II, respectively.

NELA RESEARCH LABORATORY,
CLEVELAND, OHIO.
August, 1919.

Experiments with Soy-bean Meal as a Substitute in the Army Ration are described by Capt. ARTHUR W. DOX in the *Proceedings of the Iowa Academy of Science*, 1918, XXV, 517–519. Soy-bean meal and soy-bean flour are by-products. The oil is pressed from the soy beans and the press cake is ground and sifted. The flour and meal used in the experiments contained 6.5 per cent. moisture, 44.1 per cent. protein, 3.3 per cent. fat, 5.9 per cent. crude fibre, and 35.5 per cent. carbohydrates. The experiments were conducted under the auspices of the Food Division, Sanitary Corps of the United States Army at Camp Travis, San Antonio, Texas, on messes of both officers and enlisted men; each mess included from 100 to 200 soldiers. The army ration prescribes 18 ounces of wheat flour, part of which may be replaced by other cereals. Soy-bean meal was used in soups; one and one-half ounces of the meal and one pint of boiling water was the proper ratio; they were boiled for five minutes, then the other ingredients

were added. The soup was not very palatable without proper seasoning. With seasoning a very palatable dish was prepared. For bread a mixture of 80 per cent. wheat flour and 20 per cent. soy-bean flour was used. The product was darker in color than wheat bread, but was excellent in flavor; the loaves did not attain the usual height. When more than 20 per cent. soy-bean flour was used, the loaves tended to become soggy; probably 10 per cent. would yield the best results. Unlike bran, admixture of soy-bean flour does not decrease the nutritive value of the bread, for soy-bean flour contains a high per cent. of protein or nitrogenous food, and this protein is of high quality and 90 per cent. digestible. For the same reasons soy-bean flour is preferable to corn meal.

J. S. H.

At the International Hydrographic Conference held in London in the summer of 1919, twenty-three countries were represented. The purpose was to compare and study the methods used in the several countries in order to determine the best among them and to standardize the hydrographic publications of all countries as far as possible. In the "Light Lists" now are included "wireless direction-finding stations" and "sound-ranging signal stations." It was recommended that all countries adopt "time zones" at sea, as Great Britain, France, and Italy have already done. A committee of which Rear Admiral Simpson, United States Navy, is a member is to present to the various governments the arguments for the establishment of an International Hydrographic Bureau.

G. F. S.

A Positive Ray Spectrograph. F. W. ASTON. (*Phil. Mag.*, December, 1919.)—After the positive rays have passed the cathode they traverse two very narrow slits. The resulting ribbon of rays is then spread out into an electric spectrum upon passing through a static field between two parallel plates. A part of the spectrum is allowed to traverse a diaphragm and subsequently a magnetic field between the parallel pole pieces of an electromagnet. This magnetic field deflects the rays in a direction opposite to that in which they were bent by the electric field. Rays which have the same relation of mass to charge now are brought to a focus and can be photographed. Preliminary tests indicate that the instrument gives clearly defined foci and leads the experimenter to hope that it may be used to determine whether neon is an element or an isotopic mixture.

"To make slits with beautifully parallel sides to almost any degree of fineness, .01 mm. being easily obtainable," Mr. Aston bores a hole in an aluminum cylinder and then flattens the hole out by crushing the cylinder.

G. F. S.

THE COLORIMETRY OF NEARLY-WHITE SURFACES.*

BY

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If from an assortment of papers, we had picked out the sheets which appealed to us as being white, we would be satisfied with our choice until we laid the sheets side by side. By comparison, some would be yellowish, others bluish, etc., and it would be difficult, if not impossible, to decide upon one sheet that was truly white. Problems of this character are continually arising in the paper, paint and textile industries. Up to the present time it has been sought to regulate the uniformity of product by establishing a series of standard examples which define the limits of tolerance. Leaving out of consideration the question of reproducibility, the principal objection to be urged against this mode of procedure is that the standards themselves are subject to change with time. To be sure, this difficulty has long been recognized and numerous attempts have been made to apply the methods of monochromatic and trichromatic colorimetry. However, these attempts have been unsuccessful because of the fact that the departure from white is usually so very slight that accurate measurements of this departure are out of the question. In the instrument to be described, the departure is much accentuated and is thus made amenable to accurate measurement.

Before taking up a description of the apparatus, it may not be out of place to discuss the term "white." According to Nutting[1]: "White is difficult to define and its definition is more or less arbitrary. Subjectively, white is that color in comparison with which any other color appears tinted. Objectively, the light of the midday sun[2] (blue sky light excluded), reflected from a non-selective surface, is white. White can be defined in physical

* Communicated by the Author.

[1] Nutting: "Outlines of Applied Optics" (p. 154), Blakiston.

[2] At present opinions differ as to the choice of a standard source of white light. Whether it is to be the midday sun, average daylight, or the visible radiations of a black body of known temperature, the action of some national or international body is urgently desired.

units only through its spectral energy curve." In speaking of a surface as yellow or blue, it is tacitly assumed that white light is incident on the surface. If, therefore, a body reflects selectively, it is to be called "colored," whereas, if it reflects non-selectively, it is to be called "white." According to this nomenclature it is entirely proper to speak of one surface as being "brighter" than another or "departing more from white." The term "whiter than" may not be used, because the two concepts (1) increase in brightness and (2) decrease in departure from white (saturation) are both involved.

The present discussion deals with surfaces of great brightness and small departure from white. In order to accentuate this departure, the method of multiple reflections was applied. If white light be allowed to fall on the surface that is slightly greenish, it is obvious that the diffusely reflected light will contain an excess of green. If now this light be allowed to fall on a second surface, identical with the first, the light reflected will be, relatively, still richer in green. By allowing similarly, a third and fourth reflection to take place, it is possible to accentuate the green tint very pronouncedly. If a surface be truly white, *i.e.*, non-selective, multiple reflections will affect only the intensity of the light—not its spectral distribution. As will be shown later, we have here an extremely sensitive test of selectivity. Anticipating the results to be presented it may be stated that of the many surfaces studied (papers, salt, sugar, zinc oxide, white lead, precipitated salts, etc.), not a single one has been found that does not depart noticeably from white.

Multiple reflections may be realized in a number of different arrangements, as is shown in Fig. 1. Here (*a*) represents a tube coated on the inside with the material to be tested (3 reflections); (*b*) represents two circular discs coated on the sides facing one another (3 reflections); (*c*) a hollow sphere with central disc (4 reflections). The condition sought in all cases is that no light leaving the surface after the first reflection shall illuminate directly that portion from which the light finally emerges. Clearly, the design (*d*) is faulty but (*e*) is good. While it is true that the accentuation of tint increases exponentially with the number of reflections, a limit is set because of the resultant decrease in intensity. Furthermore, preference must be given that design which lends itself most readily to the application of the surface

to be studied. Taking all of these elements into consideration the design (*b*) was finally chosen and incorporated in the colorimeter.

The degree of accentuation may be calculated with readiness by studying the change in brightness (coefficient of diffuse reflection) resultant upon the successive introduction of two different surfaces into the colorimeter. Let

I_0 = intensity of incident light.
I_1 = intensity of light after n reflections from material 1.
I_2 = intensity of light after n reflections from material 2.
R_1 = coefficient of diffuse reflection of material 1 (known).
R_2 = coefficient of diffuse reflection of material 2 (known).
n = number of reflections.
K = instrumental constant.

Then: $$\frac{I_1}{I_2} = \frac{I_0 K R_1^n}{I_0 K R_1^n} \quad \text{or} \quad \frac{I_1}{I_2} = \left(\frac{R_1}{R_2}\right)^n$$

whence $$n = \frac{\log \frac{I_1}{I_2}}{\log \frac{R_1}{R_2}}$$

For a substance of unknown brightness R_2:

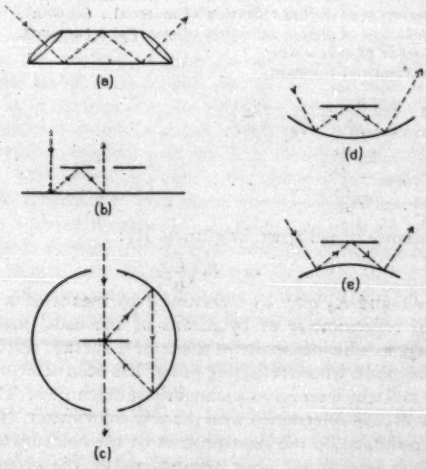
$$R_2 = R_1 \sqrt[n]{\frac{I_2}{I_1}}$$

Now R_1 and R_2 may be determined by means of a Nutting (absolute) reflectometer or by means of the usual methods of photometry, in which case use in made of a surface smoked with magnesium oxide, whose reflecting power has been determined (87 per cent.) and which serves as a standard of brightness. The intensities I_1 and I_2 are determined with the new colorimeter. The value of n is determined by the relative sizes of the colorimeter plates and of their separation. For separations of the order of the diameter of the upper disc $n = 3$ or slightly greater; as the separation decreases, n becomes larger. For the actual tests here recorded, the separation was such as to yield the value $n = 3.6$ while in a series of tests later on with a smaller separation $n = 4.2$. If we were dealing with specular reflection, n would necessarily have to be a whole number. However, we are dealing with diffuse reflection and, while n must equal at least 3, it may be considerably larger, due to the numerous reflections which take place. Since the human eye cannot detect differences in intensity less than 1 to 2 per cent. (Fechner's Law) it is clear that

the method of multiple reflections makes possible a discrimination between two surfaces whose brightness difference is, roughly, one-fourth of the above.

Considerations of a similar nature apply to the determination of the departure from white or "saturation," *i.e.*, if green light be in excess by 1 per cent. after a first reflection, the excess will be approximately 4 per cent. after multiple reflections have taken place. Considering the truly marvelous sensibility of the eye in

FIG. 1.

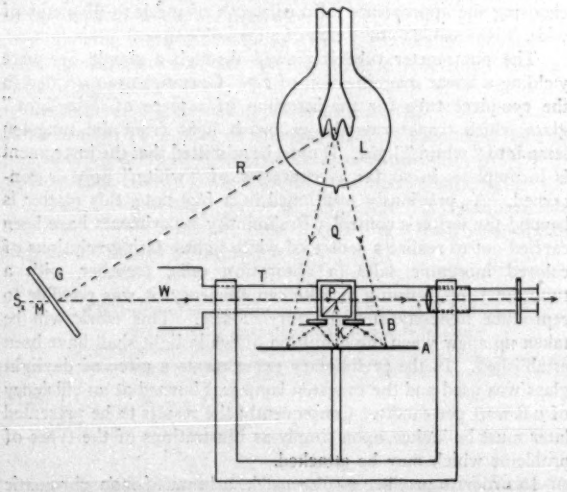


distinguishing color differences between two contiguous surfaces of large area, it would be rash to state that the new colorimeter is able to determine color differences between two surfaces which, under normal conditions, appear to be of the same brightness and tint. This much may be said, however: if the colorimetric analysis of the two surfaces is the same, the unaided eye may be able to distinguish a difference without being able to define the character of that difference.

The apparatus, as actually constructed, is shown in Fig. 2. Here *L* is a 100 watt Mazda *C* lamp which illuminates the outer

portion of the circular disc A whose upper surface is covered with the material to be studied. The light, diffusely reflected, illuminates the lower (coated) surface of the disc B, which, in turn, illuminates the central portion of the dic A. The light, after multiple reflections, passes upward through a central opening in B and is reflected horizontally by means of the photometer cube P. Another beam of light leading L is reflected from a disc of clear optical glass G, roughly ground on both sides. (Without going

FIG. 2.



into details it may be stated that the most painstaking tests have shown that such a plate reflects visible radiations non-selectively.) This light passes through the tube T and fills the upper half of the field of view of the photometer cube which has a horizontal line of demarcation. The intensity of this beam varies by rotating the disc G about a horizontal axis. A pointer, attached to the rod bearing disc G moves over a graduated scale and thus yields readings corresponding to definite positions of the plate G. Numerical values of intensities are obtained as a result of separate calibration involving the removal of plate A and the

admission of a beam of light K coming from a separate lamp (mounted on a photometer-bench) and illuminating a surface of MgO. This light reflected diffusely, is again deflected by a prism along the path K. So as not to complicate the drawing unduly, this calibrating device is not shown. The intensity of the light leaving G may be varied in the ratio 1 : 15. Whenever it becomes necessary to extend this range in either direction, a wire gauze, coated with soot, is introduced either at R or Q. Since the percentage transmission of the gauze may be regulated by choosing the appropriate ratio of width of mesh to diameter of wire, it is possible to take care of all possible cases.

The photometer tube is viewed through a simple eye-piece yielding a linear magnification of 2.5. Openings are provided in the eye-piece tube for the insertion of a piece of "daylight" glass which transforms the yellowish light from the tungsten lamp into "white" light. It must be admitted that the instrument is incomplete, in so far as character of "white" light is concerned. As previously mentioned in a foot-note, this matter is beyond the writer's control. Preliminary experiments have been carried out to realize a source of white light. Using solutions of colored inorganic salts in absorption cells, together with a tungsten lamp, burning at a known efficiency, it was possible to reproduce noonday sunlight very closely. This work will be taken up anew when the definition of white light shall have been established. In the preliminary experiments a piece of daylight glass was used and the tungsten lamp was burned at an efficiency of 0.8 watt per candle. Consequently the results to be presented later must be looked upon simply as illustrations of the types of problems which may be attacked.

In order to produce a colormatch, a beam of monochromatic light, emanating from the secondary slit S_2 of a monochromatic illuminator, is projected on the plate G and passes through it—thus, monochromatic light is superimposed on the white light from L. The intensity of the former is varied by means of a rheostat in series with the lamp illuminating the slit of the monochromatic illuminator. Color-matching is not a simple operation since three variables: (1) intensity of white light, (2) intensity of colored light, (3) wave-length of colored light have to be controlled. Proficiency is reached only after long experience.

If the surfaces A and B reflect very selectively it is difficult to

balance the markedly colored beam (K) against the white beam (W) and it will always be difficult to balance the monochromatic beam (M) against white light with the arrangement shown. Obviously a device involving "flicker" ought to be introduced to replace the simple eye-piece. While a design for such a flicker-photometer has been prepared, it was found possible to dispense with its use primarily because of the fact that the surfaces dealt with departed from white but slightly. The intensity of the monochromatic light is determined by the "method of differences," as will be shown presently.

Following the usual methods of monochromatic colorimetry, color characteristics of any surface (single reflection) are defined in terms of:

1. Brightness (B), coefficient of diffuse reflection.
2. Saturation (S), ratio of intensity of monochromatic light to total light required to produce a color-match.
3. Dominant Hue (λ), wave-length of monochromatic light.

Since the necessary mode of procedure for obtaining the brightness (B) has already been discussed it is only necessary to take up the matter of saturation (S).

Let

I_o = intensity of white light required to balance light from surface under investigation (single reflection).
I_1 = intensity of white light necessary for color-match.
I_λ = intensity of colored light necessary for color-match.

Then $I_o = I_1 + I_\lambda$ whence $I_\lambda = I_o - I_1$

then $$S = \frac{I_\lambda}{I_1 + I_\lambda} = \frac{I_o - I_1}{I_o}$$

According to this procedure, I_λ need not be measured, hence the introduction of a flicker-photometer becomes unnecessary.

The value of λ is obtained from the calibration curve of the monochromatic illuminator. If, instead of a single reflection, n reflections are realized, then the saturation is accentuated and it is necessary to extract the *nth* root of the apparent saturation so as to reduce the measurement of the conditions under which the surface is normally viewed, *i.e.*, a first reflection.

Whenever the departure from white is marked, *i.e.*, when the true saturation is 5 per cent. or more, readings are easily reproducible. Intensity measurements rarely differ by more than 1 per

cent. and the dominant hue can be fixed to within 1 to 1.5$\mu\mu$. However, when saturation values are small (less than 0.7 per cent.) measurements become increasingly difficult—particularly in fixation of the wave-length of the dominant hue.

The following table contains data on the color characteristics of a number of nearly-white substances:

Substance	Brightness	Saturation	Dominant hue λ in $\mu\mu$	Remarks
	Per Cent.	Per Cent.		
Magnesium Oxide	85	0.2	486 Blue	Fumes from burning Mg.
Magnesium Carbonate	87	0.75	578 Yellow	Scrapings from commercial black—flattened with glass.
Paper	67	0.70	489 Blue	Single sheet linen paper (thin)
Paper	74	3.0	581 Yellow	Single sheet linen paper (heavy)
White lead	69	3.8	580 Yellow	Rubbed down with pale linseed oil—paste form
Zinc Oxide (pure)	77	1.0	562 Green	Rubbed down with pale linseed oil—paste form
Zinc Oxide (leaded)	68	7.1	583 Yellow	Rubbed down with pale linseed oil—paste form

All of these substances depart markedly from white. Even magnesium carbonate, which has been used frequently as a non-selective reflector in colorimetric investigations, is definitely yellowish.

In common with others, the writer found that much training and experience is necessary before reliable measurements, of the kind presented, may be obtained. Following the well-known practice, the procedure was simplified by eliminating measurements of saturation and dominant hue and instead, determining the brightness for blue, green and red light. Color-screens of dominant hue: 440$\mu\mu$ (blue), 550$\mu\mu$ (green) and 625$\mu\mu$ (red) were, in succession, placed before the eye-piece and the brightness for these three colors was determined. While this method lacks the scientific rigor of the former, it possesses marked advantages. First of all, no standard "white" light is required; (2) no color matching is necessary; (3) it serves admirably in establishing limits of tolerance, *i.e.*, selectively, for substances which are already nearly-white.

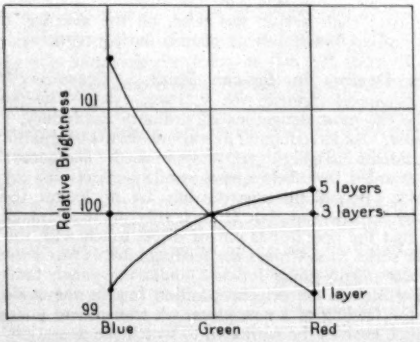
By means of this arrangement a detailed study of MgO, obtained by allowing the white smoke from burning magnesium ribbon to deposit on the colorimeter plates, was undertaken.

Altogether, five successive layers of MgO were deposited—measurements being taken after each deposit. The final thickness of layer was about 0.6 mm. The changes in selectivity of reflection are shown in the following curves: (See Fig. 3.)

While the color is decidedly bluish for one layer, it changes to yellow when five layers are employed. Curiously enough, the surface is truly "white" at three layers.

In conclusion it is to be stated that the advantages derived from multiple reflections need not be sacrificed when markedly colored surfaces are to be studied. The only difficulty here is to

FIG. 3.



get enough light for accurate measurements. A separate instrument is being developed to take care of this contingency.

Following is a summary of the preceding discussion:

1. Taking advantage of the circumstance that multiple reflections from similar surfaces accentuate selective reflection, a new colorimeter, adapted to the study of nearly-white surfaces, has been developed.
2. Measurements are presented to show that our usual standards of "white" ($MgCO_3$ and MgO) depart noticeably from this ideal.

JOHNS HOPKINS UNIVERSITY.
RESEARCH LABORATORY OF THE
NEW JERSEY ZINC COMPANY.
November 4, 1919.

Statistics on Sugar Consumption in the United States are given in the *Weekly News Letter of the U. S. Department of Agriculture* (vol. vii, No. 25, p. 3, January 21, 1920). The total consumption in 1919 amounted to over 9,000,000,000 pounds or 4,500,000 tons, while the normal domestic production is 1,000,000 tons. The average per capita consumption was 18 pounds in the year following the Civil War, and ranged from 24 to 50 pounds each year thereafter until 1890. The average yearly per capita consumption in each decade was:

1866–1875: 35 pounds.
1876–1885: 42 pounds.
1886–1895: 57 pounds.
1896–1905: 67 pounds.
1906–1914: 81 pounds.

Since 1914 each person has used, on the average, 85 pounds annually, and approximately 92 pounds during 1919. J. S. H.

Safety Devices in Tin-can Plant. (*Canadian Machinery*, through *Technical Review*, vol. v, 1919, 252.)—The power press used to be the most dangerous of ordinary machinery, except the circular saw. By introduction of various forms of guarding attachments, accidents have been greatly diminished. Dangerous overhead belts are guarded from below, spokes of fly-wheels are covered with metal disks. In making cans the lids are no longer fed into the machine by an operator, but from a tray on to a travelling feed-band, so that the operator is out of direct touch with the machine. In another series of machines the feeding table is fitted with a reciprocating movement, going forward under the punch for the stroke and coming back to the original position for the removal of punchings and the feeding of a new piece. A transparent guard in front of the punch enables the workman to watch the operation.

Another machine with which many accidents formerly occurred is the rotary cutter for slitting the sheet tin into strips. An iron guard is now placed in front of the knives for the full width of the machine, sloping down under the knives, leaving only a narrow opening for the introduction of the sheet.

These and numerous other safety devices which have been introduced have not only greatly diminished the number of injuries, but have increased output.

In this connection mention may be made of a special safety device used in one of the plants for making talking-machine records. In this work, a soft mass in the form of a flat plate about ten inches in diameter is pressed between two dies. The great danger is that the attendant may thoughtlessly place the hand between the dies. To prevent this a guard automatically moves in front of the machine, as soon as the dies begin to descend, and this will push the attendant's hand to one side in ample time to avoid crushing.

H. L.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A PECULIAR TYPE OF INTERCRYSTALLINE BRITTLENESS OF COPPER.[1]

By Henry S. Rawdon and S. C. Langdon.

[ABSTRACT.]

WHEN copper is heated in a molten bath of sodium chloride for the purpose of cleaning and softening, it has been noticed that the copper was embrittled. Under these conditions the copper is more or less in contact with iron or steel, either from a stirring rod, forceps for handling the piece or the pot used to contain the salt, and a "galvanic couple" with the copper as cathode would be formed.

Experiments were made with small rods of copper and mild steel which were made either anode or cathode in a bath of molten salt and with an e.m.f. of approximately 6 volts. The brittleness of the copper rods was compared with untreated material by bending the specimens back and forth with one end firmly clamped.

The copper rod which was an anode was as tough and soft as the original and required practically the same number of bends to cause it to fracture. The cathode copper was found to be very brittle.

Microscopic examination showed the anode copper to be perceptibly smoother on the surface than the original material; the structure was that of annealed copper. In the cathode copper rod the crystalline boundaries on the surface are well defined, and the intercrystalline boundaries for an appreciable depth within the metal are made wider.

The probable explanation of embrittlement of the copper when it is made the cathode is that an appreciable amount of metallic sodium is formed by the electrolysis which immediately alloys with the copper, the attack being selective towards the grain boundaries rather than forming an alloy layer of uniform thickness upon the outside.

* Communicated by the Director.

[1] Technologic Paper No. 158.

PHYSICAL TESTS OF MOTOR-TRUCK WHEELS.[1]

By C. P. Hoffman.

[ABSTRACT.]

TECHNOLOGIC Paper 150 relates to certain tests made for the military departments of the Government at the Bureau of Standards. A brief summary of this work is given below.

In designing Class B military truck it was found desirable to develop a metal wheel having the good qualities of all the wheels on the market. No comparative values were available, however, and there was no time for service tests. The Bureau of Standards was therefore called upon to make laboratory tests.

The wheels tested were made of cast steel, pressed steel, wrought iron and wood by various manufacturers. Each wheel was supported upon a shaft which fitted the bore of the hub and a radial compressive load was applied to the rim midway between two spokes by a bearing block which fitted the rim.

A "side thrust" test was also made by supporting on a similar shaft and applying a concentrated load on the rim in a direction parallel to the shaft.

Using the information obtained from these tests, a hollow spoke and rim cast wheel was designed for the Quartermaster's Department which was called the "Composite Wheel."

When tested, these proved satisfactory and were adopted for use on the Class B military truck.

The results of tests upon twenty-one wheels are given. The deformations of the wheels in the radial compression test were recorded for four points on the rim spaced 90 degrees apart. Load deformation graphs plotted from these data are given from which the proportional limit and elastic resiliences of the wheels at loads up to that limit are computed.

Similar data were obtained from the "side thrust" tests and graphs plotted. The proportional limit and elastic resiliences were obtained in the same way.

It is obvious that the strongest wheel is not necessarily the best for actual service. The elastic resilience of the wheel under low loads is also important as it measures the capacity of the

[1] Technologic Paper No. 150.

wheel to absorb shocks. This elastic resilience for unit weight of material served as the chief basis of comparison between different types of wheels.

A photograph and description is given for each wheel with the weight and a chemical analysis of the material for the metal wheels.

In designing a truck wheel, careful consideration should be given to several conflicting elements in order to obtain the best results. This paper gives experimental data which should serve as a guide in such work.

One of the cast steel wheels was tested in radial compression and the strain-gauge used to determine the actual deformation of the material in the wheel. Observations were made on the rim, on the spokes and on the hub.

The average modulus of elasticity was determined for specimens cut from the wheel and this value used in computing the stress at places where the deformation was observed.

From these data, graphs were plotted showing the stress in the wheel at forty-eight gauge lengths for loads on the wheel up to 60,000 pounds. Due to the short gauge length (2 inches) results of great precision were not to be expected but in this case the results were very satisfactory.

Stresses in wheel under load.—

Compressive stresses were found in all parts of the rim except the section between the spokes adjacent to the loading block. That section was subjected to tensile stresses by the behavior of the spokes. The only excessive stress in the hub was at the junction of the two spokes adjacent to the loading block where the tensile stress reached the proportional limit of the material when the applied load was 50,000 pounds.

The stresses in the spokes were all within the proportional limit of the material except for two gauge lines on one spoke adjacent to the hub. Possibly these were located at a thin section of the casting.

These strain-gauge results, the first of their kind so far as is known, should lead to the determination of the stress in wheels tested for investigational purposes. Only in this way can the most satisfactory distribution of the material be obtained. Such data allow the re-design of a wheel so as to avoid excessive stresses which cause failure in service tests.

INVESTIGATION OF THE COMPRESSIVE STRENGTH OF SPRUCE STRUTS OF RECTANGULAR CROSS-SECTION AND THE DERIVATION OF FORMULAS SUITABLE FOR USE IN AIRPLANE DESIGN.[a]

By James E. Boyd.

[ABSTRACT.]

TECHNOLOGIC Paper 152 describes certain tests of spruce, particularly with reference to suitability for use in airplane construction. The work relates chiefly to the derivation of formulas to guide the designer and engineer.

Compression tests were made on 58 square-end and 24 round-end spruce struts of uniform cross-section approximately 1.75 inches square. The length of the struts varied from 12.625 inches (slenderness ratio 25) to 126.25 inches (slenderness ratio 250). Complete measurements showing compression, lateral deflection and load up to the ultimate, were made on all the struts, the longer struts being tested to destruction. In addition, cross bend tests were made on representative specimens to determine the modulus of elasticity, resilience, and modulus of rupture. Complete data are given for three representative struts and summaries of the results on all.

These experimental results are compared with Rankine's formula, Euler's formula and the rational formula for eccentric loading. The constants were calculated from the experimental data.

Round-End Struts.—

For round-end struts the rational formula gives the best results over the whole range, but is inconvenient to use. Rankine's Formula:—

$$\frac{P}{A} = \frac{5200}{1 + \frac{L^2}{3000r^2}} \qquad (1)$$

for short struts (slenderness ratio <80) and Euler's Formula:—

$$\frac{P}{A} = \frac{16{,}000{,}000}{\left(\frac{L}{r}\right)^2} \qquad (2)$$

for slender struts (slenderness ratio >80) gave results within the experimental error.

[a] Technologic Paper No. 152.

Square-End Struts.—

For square-end struts accurately fitted to rigid supports Rankine's Formula:—

$$\frac{P}{A} = \frac{5200}{1 + \frac{L^2}{12{,}000r^2}} \qquad (3)$$

gave results within the experimental error.

This condition is almost never realized in practice so that values between those given by (3) and (1) should be used in square-end construction, depending on the manner of fixing the ends. In particular, ordinary airplane pin connections should be considered as round ends, both in the plane of the pins and at right angles to it.

In the formula given above—

P = ultimate load in pounds.
A = cross-section area in square inches.
L = length in inches.
r = radius of gyration in inches.
$\frac{L}{r}$ = slenderness ratio.

For testing woods for use in struts, compression tests on slender round-end struts $\left(\frac{L}{r} = 200\right)$ with the use of Euler's formula gives an easy method of determining the modulus of elasticity, which agrees well with values obtained from cross-bend tests.

The results of this experimental work on spruce struts of uniform cross-section having shown the applicability to these struts of the rational formula for eccentric loading and its limiting case for central loading (Euler's formula), the analogous formulas for a certain type of tapered strut were developed.

In these struts the moment of inertia varies according to the law $I = Cx^2$; where "x" was the distance measured from some point beyond the end of the strut. Struts of this form approximate closely the tapered struts used in airplane construction.

The formulas for eccentric loading are complicated, but the results for central loading corresponding to Euler's formula are simple, and, by the aid of a graph, are easily applied.

A graph for this purpose is given and a number of approximate methods are discussed.

LOAD STRAIN GAUGE TEST OF 150-TON FLOATING CRANE FOR THE BUREAU OF YARDS AND DOCKS, U. S. NAVY DEPARTMENT.[1]

By Louis J. Larsen and Richard L. Templin.

[ABSTRACT.]

TECHNOLOGIC Paper 151 reports the tests of a floating crane which at present is of interest from an engineering point of view.

The fact that a floating crane failed under load on the Panama Canal made it desirable to test a 150-ton revolving floating crane built for use at the Navy Yard, Norfolk, Va. This structure is statically indeterminate and strain-gauge measurements were taken under load to determine the stress in the more important members.

This crane represents the most advanced type of revolving floating crane of large capacity. The jib is a tapering Pratt truss, hinged to the superstructure in the lower chord and connected to the luffing screws at the upper chord by suitable links. The length of the links and the location of the luffing screws are such that a nearly direct pull is exerted on the upper chord of the jib for all positions. The superstructure, exclusive of the jib, consists of two sub-divided triangular trusses rigidly connected by cross-bracing. The entire revolving load is transmitted by the triangular trusses to the pontoon through a pintle, the pintle being an inverted pyramidal-shaped member built up on four posts which transmits its load at the apex to a thrust bearing on the deck of the pontoon. The pintle is supported laterally on a tower consisting of six legs arranged in the form of a hexagon, the legs of the tower being carried through the deck to the framing of the pontoon. The tower is framed into the hull in such a manner as to make the pontoon act as a large girder in resisting the forces induced by a crane load. The pintle rotating within the tower makes it possible to revolve the superstructure with the live load to any position.

Readings were taken at various points of the deck to determine the magnitude, and, if possible, the position of the maximum stress in the upper deck plate; on the tower members to determine whether the tower acted as a unit; around the manhole in the tower legs to find the effect of such an opening; on the pintle to determine the magnitude of the stress in these members,

[1] Technologic Paper No. 151.

and on various members of the superstructure to determine the manner in which the loads were carried down to the pintle.

Gauge lines were placed on two opposite sides of every member tested, and where possible, on all four sides. Gauge lines were laid out on the deck of the pontoon for the purpose of determining the amount of stress developed in the plates of the pontoon deck and to check the computed locations of the maximum bending moments.

Strain-gauge readings were taken with a 10-inch Berry Strain-Guage, it being possible to read the change of length between the points of the instruments directly to the nearest 0.0002 inch, and by estimation to 0.00002 inch.

The material used for loading the crane consisted chiefly of armor plate and scrap iron of known weight. The loading was so arranged that each member on which measurements were taken, was subjected to the maximum possible range of stress.

The strain-gauge work done on this structure showed that all stresses on the various members were within safe limits.

The stresses in the deck were found to be low.

The maximum stresses in the outer edge of the tower legs are 17,000 pounds per square inch compression and 13,500 pounds per square inch tension.

The maximum stress in the pintle post is 18,000 pounds per square inch compression.

The stresses in the superstructure and in the luffing screws due to the load are not excessive.

CEMENTS FOR SPARK PLUGS.[1]

By Homer F. Staley.

[ABSTRACT.]

THE use of cements for sealing electrodes into spark-plug porcelains has been found to be attended by serious difficulties in high temperature engines such as airplanes. Among these are: promotion of oxidation and destruction of the electrode wires by reactions taking place in the cement and between the cement and electrode wires; breaking of spark-plug porcelains caused by difference in coefficients of thermal expansion of electrode wires

[1] Technologic Paper No. 155.

and porcelain; and cracking of cement, with consequent gas leakage, due to the same cause. A cement composed of silicate of soda and raw kaolin has been found to give little trouble from chemical action. In order to avoid the difficulties attending the use of any form of cement, the use of a mechanical seal at the top of the porcelain has been tried with promising results.

AREA MEASUREMENT OF LEATHER.[*]

By Frederick J. Schlink.

[ABSTRACT.]

THIS paper deals with the investigation of area measuring machines used for integrating the area of leather hides and skins. The importance of the problem of area measurement in view of the enormous amount and value of leather handled annually on this basis ($450,000,000 in U. S. A.) is indicated. The principles of design involved in typical machines are set forth in detail and an analysis is made of the sources of the serious errors which commonly exist and of the means available for detecting and correcting them, including a complete regime for the determination of the performance of the machine tested with regard to both the accuarcy and consistency of its determinations. Numerical data illustrative of the various errors and performance characteristics of typical measuring machines are tabulated in detail.

HYDROGEN ION CONCENTRATION IN DRY CELLS.[†]

By H. D. Holler.

[ABSTRACT.]

THE potentials of electrodes consisting of mixtures of Acheson graphite with three different manganese ores and a chemically prepared oxide were measured in ammonium chloride solutions of different hydrogen ion concentrations. The potential of the electrodes containing the ores was found to be a logarithmic function of the hydrogen ion concentration, while the potential of electrodes containing the chemically prepared oxide was found to be independent of hydrogen ion concentration. The potential

[*] Technologic Paper No. 153.
[†] Scientific Paper No. 364.

of the ores was found to decrease in acid solution and to increase in alkaline solutions. The relation found between the potential of the manganese dioxide electrode and hydrogen ion concentration, explains variations in open-circuit voltage of dry cells containing a given ore and also accounts for a portion, at least, of the polarization of dry cells on discharge.

THE METALLOGRAPHIC FEATURES REVEALED BY THE DEEP ETCHING OF STEEL.[1]

By Henry S. Rawdon and Samuel Epstein.

[ABSTRACT.]

THE deep-etching of steel by means of concentrated acid, *e.g.*, hot concentrated hydrochloric acid, is a very important means of revealing the structural condition of such material. The features revealed may be of three types: Chemical—heterogeniety due to segregation, to composition changes accompanying welding, carburization and similar process, to lack of solution and uniform distribution of special addition elements in alloy, steel, etc.; Mechanical—initial stresses due to preliminary mechanical and thermal treatment; Physical—internal fractures and similar discontinuities within the metal.

Steel which is heterogeneous in its chemical composition shows a characteristic roughened surface when etched, corresponding to the variations in composition. This roughening is due to the greater solubility of certain portions particularly the non-metallic inclusions, sulphide, oxide, etc., and to the deepening and widening of the pits resulting upon the removal of these inclosures.

As specimens typical of highly stressed material, hardened steel balls were used. The stresses, due to the mechanical and thermal treatment the balls had received, were often of sufficient magnitude as to cause the balls to crack spontaneously when subjected to the action of concentrated acid. The behavior of steel in this respect is identical with the corrosion-cracking of brasses and bronze under certain conditions.

Physical discontinuities, which may exist within the steel, usually occur as tiny cavities or pores, giving rise to "spongy" metal which is quite readily detected. Certain discontinuities are of the

[1] Technologic Paper No. 156.

nature of internal fractures, the metal still being in such intimate contact, however, that they are detected only with extreme difficulty. This type occurs rather abundantly in defective rails of the "transverse fissure" type. Similar defects have been found in forgings such as steel axles and tires. Deep etching reveals these internal fissures as short cracks which appear to bear a definite relation in their arrangement to the direction of the stresses to which the piece had previously been subjected.

The presence of these defects in steel previously to etching has never been demonstrated by previous investigators due to the lack of a suitable method. Hence various conflicting opinions have been held as to their nature and the seriousness of the defect. In order to show the presence of such internal cracks a special magnetic method was used. The specimen was polished as for microscopic examination and after magnetizing was bathed in a suspension of *fine* iron dust in kerosene. Discontinuities in the metal were clearly shown by the arrangement of the particles of iron dust along their course. Subsequent etching tests showed that each "crack" revealed by the etching is due to the widening and deepening of a *preëxisting* internal fracture in the steel. These defects are essentially fractures circular in area which occur across what is otherwise sound metal. By suitable means the metal may be opened up along the line of the defect showing that there is a definite discontinuity within the metal and no coherence at all. These areas are identical in appearance with the starting point of very serious defects known as "transverse fissures" in rails.

ESTIMATION OF NITRATES AND NITRITES IN BATTERY ACID.[1]

By L. B. Sefton.

[ABSTRACT.]

FROM among the various methods suggested for the estimation of nitrates and nitrites in small amounts and admitting of a sulfuric-acid medium, three methods for the determination of nitrates —the Diphenylamine, the "Hydrostrychnique," and the Brucine—and three for the determination of nitrites—the Iodide, the Indol,

[1] Technologic Paper No. 149.

and the Dimethylaniline—were selected and studied with reference to their use in testing battery acid.

The Diphenylamine test for nitrates and the Iodide test for nitrites were found to be wholly unreliable. It was found impossible to estimate nitrates in the presence of nitrites: the "Hydrostrychnique" and the Brucine test reacted with nitrites in the same way as with nitrates so that the results of these methods must be expressed in terms of nitrates and nitrites. In the absence of iron, the "Hydrostrychnique" or a modification of the Brucine test is recommended. In the presence of iron, only the original Brucine test may be used.

It was found that nitrites could be estimated in the presence of nitrates and best by the Dimethylaniline method.

A NEW INTERFERENTIAL DILATOMETER.[10]

By Irwin G. Priest.

[ABSTRACT.]

THIS paper describes new instruments and methods for measuring very small changes in the lengths of samples which are too small to be examined by the Fizeau interferential method. Only a single small pin is required as a sample.

The method of measurement depends upon the change in width of interference fringes instead of their displacement as in the Fizeau method. The outline of the method on this basis is briefly:

1. One of a pair of nearly, but not quite, parallel interferometer mirrors is supported at one point by the sample and at two other points by a standard substance of known expansivity, the perpendicular distance from the bearing point of the sample to the line connecting the bearing points of the standards being known.

2. The standard and the sample are so adjusted that the fringes are parallel to the line connecting the bearing points of the standard.

3. Any difference in expansivity of the sample and the standard causes the interference fringes to change their widths with change in temperature. The number of fringes between two fixed reference lines on one of the mirrors is determined at each of the two temperatures in question.

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[10] Scientific Paper No. 365.

4. From the above data the difference in the expansion of the standard and the sample can be computed.

The new method gives results of the same accuracy as the Fizeau method, while it has the following advantages over the latter:

1. Only one small pin is needed for a sample.

2. Contact errors are decreased and the error due to "creeping" of the cover plates is eliminated.

3. Computations are simplified by having the standard and the sample nearly equal in length.

4. The trouble of counting fringes while the temperature is changing is eliminated entirely without the necessity of making observations on fringes of more than one wave-length.

5. The correction for change of refractive index with the temperature and pressure of the air in the container is eliminated without evacuating the container.

6. The method is especially advantageous in determining small differential expansions, for the difference in expansion of small samples may be determined directly by carrying them together through the same temperature cycle.

PREPARATION AND REFLECTIVE PROPERTIES OF SOME ALLOYS OF ALUMINUM WITH MAGNESIUM AND ZINC.[11]

By R. G. Waltenberg and W. W. Coblentz.

[ABSTRACT.]

THIS paper gives the manner of preparation and determination of the spectral reflective properties of alloys of aluminum with magnesium and with zinc.

The reflectivity measurements were made with a spectroradiometer consisting of a mirror spectrometer, a fluorite prism and a vacuum bismuth-silver thermopile. It was found that all of these alloys tarnish in time and hence are not suitable for mirrors where permanency is of prime importance. The compound of aluminum and magnesium, Al_3Mg_4, deteriorates less rapidly than any of the other alloys examined and could be used in apparatus where a highly reflecting mirror is desired for a short time. A re-

[11] Scientific Paper No. 363.

flectivity of 92 per cent. at 0.7μ was obtained with this compound.

The zinc-aluminum alloy has a minimum of reflectivity at 0.9μ. An examination of pure zinc disclosed a similar reflectivity minimum at 1.0μ.

THE DETERMINATION OF CELLULOSE IN RUBBER GOODS.[12]

By S. W. Epstein and R. L. Moore.

[ABSTRACT.]

AFTER a discussion of the value of a procedure for determining cellulose in rubber goods and consideration of the lietrature on the subject, the proposed method is discussed.

Method. Sample is digested with cresol at 160–185° C. for four hours to dissolve the rubber. Filtration is facilitated by addition of 200 c.c. of petroleum ether. After washing with benzol, 10 per cent. solution of hydrochloric acid, water, and acetone, the material is dried and weighed. It is then acetylated by heating for thirty minutes at 75° C. in a mixture of 15 c.c. of acetic anhydride and 0.5 c.c. of concentrated sulphuric acid. This is filtered on a weighed Gooch, washed with 90 per cent. acetic acid and then with acetone and dried and weighed. Loss in weight is recorded as cellulose.

Under *Results of Analysis* are given a number of test compounds, containing varying amounts of cellulose in the presence of various combinations of compounding ingredients. The results by method given indicate its gratifying accuracy. A number of alkali reclaims are given along with cellulose content as obtained by method proposed.

It is shown how the percentage of cotton can be obtained in the presence of leather.

Leather, wood, jute, and cork are considered. These are broken down by cresol at 185° C. For this reason it is suggested that rubber be digested in cresol for sixteen hours at 120° C. when the presence of these is suspected. At this temperature the basic substance of these materials is retained intact.

Acetylation gives:

95 per cent. of the wood.
90 per cent. of the jute.
70 per cent. of the leather.
21 per cent. of the cork.

[12] Technologic Paper No. 154.

An approximation of the amount of the cork present is obtained by treating the residue after acetylation with 2 per cent. solution of sodium hydroxide and strong bromine water, in order to give the unacetylated cork. The loss in weight represents 70 per cent. of the total amount of cork present.

It was found impossible to determine each of these ingredients separately, and therefore it was decided to determine them collectively by the acetylation method, and to test for the presence of each by means of proper stains and microscopic examination.

Rubber Plant Survey of Western North America.—HARVEY M. HALL and THOMAS H. GOODSPEED (*University of California Publications in Botany*, 1919, vii, 183–264) give an account of chrysil, a new rubber, of high grade, which vulcanizes without difficulty. *Chrysothamnus*, or rabbit bush, is a genus of shrubs; its most important species is *Chrysothamnus nauseosus*, of which 22 varieties are known; plants of 12 of these varieties were examined and found to contain chrysil. The plants of this species are large shrubs; they grow readily from seed, and attain maturity in six to eight years; the average weight of a plant varies from 4 to 6 pounds. The species ranges throughout western North America, is most abundant in Colorado, Nevada, and Utah, and often occurs on alkaline flats. The plants with the largest chrysil content were found in Nevada and California. The chrysil occurs in the cells of the plant and not as a latex; it is most abundant in the tissues at the soil line. The cortex contains most chrysil, followed by the medullary rays; young twigs and leaves contain but a slight amount; of the root, only the upper portions (4 inches) contain chrysil. The average chrysil content varied from 2.83 to 1.97 per cent. or less, according to the species. One individual plant yielded 6.57 per cent. The rubber was obtained from the finely ground plants. Fats and similar substances were removed by extraction with acetone. The fat-free residue was dried, and then extracted with benzine to obtain the chrysil. Hall (*Ibid*, 1919, vii, 159–181) describes the varieties of *Chrysothamnus nauseosus* and their geographical distribution. According to Hall and Goodspeed (*Ibid*, 1919, vii, 265–278), rubber also occurs in certain other species of *Chrysothamnus*, and in certain species of the genus *Haplopappus*. In some species rubber was present to the same extent in root and stem (*e.g., Haplopappus nanus*); in other species the root contained practically all the rubber present in the plant (*e.g., Haplopappus ericoides*). Sixty-four other species of shrubs were tested, and found not to contain rubber.

J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE COMPOSITION OF THE OIL FROM THE SEED OF THE HUBBARD SQUASH.[1]

By Walter F. Baughman and George S. Jamieson.

[ABSTRACT.]

OIL expressed from squash seed by an expeller was refined by the well-known alkali process and bleached with fuller's earth. The refined oil had a yellow color and a bland fatty taste. The unsaturated fatty acids were separated from the saturated acids by the lead salt ether method and bromine addition products were prepared. Analyses of these compounds gave the amounts of oleic and linolic acids in the original oil. Methyl esters were prepared from the saturated acids and were subjected to fractional distillation under diminished pressure. From the iodine numbers and saponification values of the different fractions and the residue the amounts of unsaturated acid were calculated, the mean molecular weights of the saturated acids were found, and the weight of each saturated acid in each fraction was calculated.

The Hubbard squash seed oil was found to consist of the following:

Glycerides of	Palmitic acid	12.73 per cent.
	Stearic acid	6.12 per cent.
	Arachidic acid	0.04 per cent.
	Oleic acid	36.58 per cent.
	Linolic acid	43.34 per cent.
	Unsaponifiable matter	1.06 per cent.

THE COMPOSITION OF OKRA SEED OIL.[2]

By George S. Jamieson and Walter F. Baughman.

[ABSTRACT.]

OIL expressed from okra seed by an expeller was examined physically and chemically by the methods used for Hubbard

* Communicated by the Director.

[1] Published in *J. Am. Chem. Soc.*, **42**, 152–7 (Jan., 1920).

[2] Published in *J. Am. Chem. Soc.*, **42**, 166–70 (Jan., 1920).

squash oil (see above). The oil, which amounts to about 15 per cent. of the seed, was found to have the following composition:

Glycerides of	Palmitic acid	27.23 per cent.
	Stearic acid	2.75 per cent.
	Arachidic acid	0.05 per cent.
	Oleic acid	43.74 per cent.
	Linolic acid	26.62 per cent.
	Unsaponifiable matter	0.37 per cent.

A CHEMICAL STUDY OF THE RIPENING AND PICKLING OF CALIFORNIA OLIVES.[3]

By R. W. Hilts and R. S. Hollingshead.

[ABSTRACT.]

THE results of an investigation of the chemical changes which occur in California olives during ripening and during pickling indicate that the best index of maturity for olives, both fresh and pickled, is the percentage of oil in the fruit flesh. Allowance, of course, must be made for variations due to the variety of the olives and the locality in which they are grown. A minimum oil content of 17 per cent. in the flesh is offered as a tentative standard of maturity for Mission olives and other common varieties, except the Manzanillo, Ascolano, and Sevillano. A minimum oil content of 15 per cent. is recommended as a tentative standard for Manzanillo olives. No standards for maturity are recommended for the large-fruited olives, Ascolano and Sevillano, which must be gathered when relatively immature. These olives, however, should not be sold under the designation "ripe."

Because of the great variations noted in the composition of olives of the same variety grown in different localities, it probably will never be practicable to set definite and hard fixed minima for oil in mature olives, and the proposed standards must be applied with caution.

It was found that some of the abuses, the report of which led to this investigation, did exist, immature olives having often been pickled and colored to simulate pickled ripe olives. The data given in the bulletin will make possible the detection of gross frauds of this nature.

[3] Dept. Agr. Bull. 803 (Jan. 24, 1920).

THE OCCURRENCE OF MELEZITOSE IN HONEY.[4]

By C. S. Hudson and S. F. Sherwood.

[ABSTRACT.]

IT has been known since ancient times that bees collect mannas during droughts because floral nectar is not then abundant. Turkestan manna and likewise a manna from the European larch tree have long been known to contain the rare sugar melezitose, and recently the authors[5] found over 70 per cent. melezitose in a manna from the Douglas fir of British Columbia. The identification was made by chemical means and also by optical crystallographic examination by Dr. Edgar T. Wherry.[6] While considering the possibility that melezitose may have been present in some kinds of honey and escaped detection in the past, the authors received a sample of comb honey, of honey-dew type, from Port Royal, Pennsylvania, which had crystallized solidly in nearly all the cells. The crystals were not d-glucose, the sugar that frequently crystallizes from honey, but were pure melezitose. Two samples of honey-dew honey from Maryland have also been found to contain crystalline melezitose. An investigation by Dr. Edgar T. Wherry of the origin of these three lots of honey discloses that the bees collect a sweet fluid deposited on the young twigs of the Virginia pine (*Pinus virginiana*) by a soft scale insect (*Toumeyella parvicorne* (?) Ckll.), or at other times by an aphid (*Lachnus pineti* (Fab) Koch.), and store away this material in place of floral nectar. The fluid itself was found to contain much melezitose. Analytical data on this type of honey are recorded, and a way for the approximate estimation of melezitose in such products is described. Since melezitose has already been identified in mannas from two conifers, namely, the European larch and the Douglas fir, and is now found in an exudation from a third, the Virginia pine, the question naturally arises whether melezitose may not be present in the sap of most coniferous trees.

[4] Published in *J. Am. Chem. Soc.*, **42**, 116 (1920).
[5] Hudson and Sherwood, *J. Am. Chem. Soc.*, **40**, 1456 (1918).
[6] Wherry, *J. Am. Chem. Soc.*, **42**, 125 (1920).

A Cheap and Simple Micro-balance. J. H. SAXBY. (*Proc. Phys. Soc. London*, vol. xxxii, Part I.)—The balance costs about eighteen pence, is designed for maximum loads of 5 milligrams to as many decigrams, has an accuracy of one part in 1000 and is rapid in action. A horizontal beam is fixed in position. To each end is attached a vertical beam supported slightly above its centre of gravity and turning readily about a horizontal axis. A light thread is stretched from the lower end of one vertical beam to the lower end of the other. Its length is about 2 feet. The load to be weighed is suspended at the middle of this thread. The weight draws the two ends of the vertical beams together and thus a considerable sinking is caused. A calibration curve is obtained by the use of known weights.

The beams were metal ("Meccano") strips perforated at regular intervals with holes.

G. F.S.

Note on a Modified Form of Wehnelt Interrupter. F. H. NEWMAN. (*Proc. Phys. Soc. London*, vol. xxxii, Part I.)—For the ordinary Wehnelt interrupter a P.D. of from 80 to 100 volts is needed and besides its life is limited by the disintegration of the metal. In the modified type a plate of aluminum of 50 sq. cm. area and a platinum wire sealed in a glass tube are the electrodes. The minimum potential difference necessary is 18 volts and the interrupter can work for ten hours with little destruction of the platinum wire. When used with a direct current the wire must be made the positive electrode. The current is, of course, intermittent and the frequency of the interruptions increases with the applied volts.

When the interrupter is used with alternating current the wire is positive with respect to the aluminum. When joined in series with the primary of an induction coil and with 100-volt A.C. mains the current in the secondary of the coil was unidirectional and very steady—suitable for X-ray production.

G. F.S.

The Constitution of the Elements. F. W. ASTON. (*Nature*, December 18, 1919.)—By the use of his positive-ray spectrograph the author finds carbon and oxygen to be pure but neon, chlorine and mercury to be mixtures of isotopes. Neon is a mixture of isotopes of atomic weights 20 and 22, chlorine of at least two isotopes of atomic weights 35 and 37, while mercury consists of a mixture of three or four isotopes with atomic weights in the vicinity of 200.

A fact of great significance is that of more than 40 determinations of atomic and molecular weights, all, with no exception at all, prove to be whole numbers, carbon and oxygen being taken as 12 and 16.

G. F.S.

NOTES FROM THE U. S. BUREAU OF MINES.*

CO-OPERATIVE PETROLEUM WORK, WYOMING.

By T. B. Tough and B. H. Scott.

THE ROCKY MOUNTAIN PETROLEUM ASSOCIATION was formed to raise a fund to be placed at the disposal of members of the staff of the Bureau of Mines for giving advice and assistance in regard to the drilling of wells in the Wyoming oil fields, since preliminary examination indicated that operations on government lands were resulting in considerable waste in both oil and gas production. In this way $30,000 was made available, and work was started on Buck Creek Well No. 4, in the Lance Creek field, which had been invaded by water. Between September 16 and November 14, 1919, the water was successfully shut off and the well began flowing at the rate of 700 barrels per day. The value of the output of this well for the subsequent month alone will more than repay the cost of such work in the entire Rocky Mountain region for a year. In California, where similar work has been carried on, the result has been such an improvement in general practice that companies that formerly completed only 30 per cent. of their wells in good condition now complete 80 to 90 per cent. Another result of such work is that production in California has been maintained steadily from year to year without the help of phenomenally large wells to maintain the output.

REMOVAL OF LIGHTER HYDROCARBONS FROM PETROLEUM.

By J. M. Wadsworth.

CALIFORNIA practice has developed the desirability of subjecting petroleum to a preliminary refining to remove the lighter hydrocarbons. When the crude oil is to be burned, it is obviously wasteful not to first remove the valuable light constituents. As a safety precaution it is also desirable to remove the lighter fractions from oil before storage to prevent losses from evaporation.

* Communicated by the Director.

In addition, such a process dehydrates and cleans the oil. The character of the California oil and the use to which it is put accentuates the desirability of such a method. In considering the construction of such a plant the following factors need to be taken into consideration: Will the volume of residuum be large enough for heat exchange with the crude? Can the vapors be used to reduce the cooling water requirements? What products will be made and what volume of each? Will the saving of fuel justify the capital and maintenance on the apparatus required? What type is suitable for the oil? What method will best recover the heat from the stack gases? Has every possible provision been made for the recovery of heat? A number of California plants, having a total capacity of 2,300,000 barrels of crude monthly and producing an average yield of 18 per cent. "tops," or light fraction, were studied and the detailed results of this study are presented in Bulletin 162 of the Bureau of Mines. The cost of the plants per barrel daily capacity varied from $2 to $28.55; the total fuel oil consumed under the stills and boilers ranged from 1.07 to 3.69 per cent. of the crude treated; and the combined efficiency of furnace and stills ranged from 34.8 to 66 per cent.

CONDITIONS IN THE EUROPEAN PHOSPHATE MARKET.

By W. C. Phalen.

THE farmers of France have had since 1914 only about one-third of the phosphate ordinarily consumed and even though there are large deposits in the French colonies of Tunis and Algiers, only 80,000 tons were brought to France in the first quarter of 1919, as compared with 122,000 tons in the same period of 1918, the difficulty being one of transportation. It is reported to be the intention of the French government to regulate the exportation of phosphate from Africa, which has been going freely to England and Italy, so as to assure an adequate supply for France. Only about one-half of the needs of France have been allocated, owing to the difficulties of transportation and of the 700,000 tons allocated for the first six months of 1919 only 30 per cent. was actually imported. The French specifications as to soluble phosphate, iron, and alumina are not so strict as in other European countries, and the market there is therefore in a position to take

care of considerable amount of medium to low-grade phosphate.

In Italy the demand for phosphate is growing because of the need for increased crop production. Before the war the importation of phosphate into Italy was largely controlled by German firms, but a number of Italian importers and consumers are in direct touch with American producers.

About two-thirds of the phosphate imported into Spain comes from Africa and the remainder from Florida. About a half million tons of superphosphate were consumed in Spain yearly before the war, but only about one-half that was consumed in 1918. It has been estimated that two million tons could be consumed yearly to advantage, but the growth of the market will doubtless be slow. Of the amount of superphosphate used in 1913, 80 per cent. was manufactured in Spain and the rest imported from England, France, Belgium, and Holland.

MINOR NOTES.

Storage Battery Locomotives.—At a conference held in Harrisburg, Pa., January 27th, safe use of storage-battery locomotives underground was discussed and the chief inspector of the Pennsylvania Department of Mines stated that if the locomotives were tested and approved in accordance with Schedule No. 15 of the U. S. Bureau of Mines, they would be acceptable to the State of Pennsylvania.

Incombustible Gas.—Some gas wells of the mid-Continent field yield gas that is practically incombustible. Samples collected from a well drilled recently near Homing, Oklahoma, showed less than 10 per cent. hydrocarbons.

Ultra-rapid Moving Picture Photography. H. Abraham, E. Bloch, and L. Bloch. (*Comptes Rendus, Acad. des Sciences,* vol. clxix, No. 22, 1919.)—A small Leyden jar charged to 5000 volts discharges across a gap and illuminates the object to be photographed. As soon as the jar has discharged it recharges from a large condenser. The sparks pass at the rate of more than 50,000 per second, and have a duration of about a millionth of a second. They are therefore practically instantaneous. The successive images are received on a sensitive film in rapid motion. "It is easy to take moving picture views with a speed of more than twenty thousand photographs per second."

G. F. S.

Experiments on Gravitation. L. MAJORANA. (*Comptes Rendus, Acad. des Sciences,* vol. clxix, Nos. 15 and 17, 1919.)—A lead sphere of mass 1274 g. suspended from the right arm of a balance was counterpoised by a similar sphere on the left arm. Both spheres are surrounded by walls of the same shape. The first sphere has its centre coincident with the centre of a cylinder with vertical axis which can be filled with mercury of mass 104 Kg. The liquid is kept from touching even the protecting wall about the lead sphere. A vacuum was maintained within the balance case and all thermal, electrical, magnetic, and electromagnetic effects were eliminated. As the result of a lengthy series of experiments, conducted at night or on days of general strike, it was found that the lead suffered a loss of weight of 0.0009 mg. when it is surrounded by the mercury, that is, a loss of 7.10^{-10} of its weight. This is of interest, since hitherto it has been believed that the force of gravity acts through matter just as if it were a vacuum.

G. F. S.

American Diet Changing. (*Weekly News Letter, U. S. Department of Agriculture,* January 21, 1920, vol. vii, No. 25, p. 8.)—Whether it is because of the increased cost of meat or because people's tastes have changed, the fact remains that Americans are eating 8 per cent. less meat than they were twenty years ago. This is disclosed in a recent dietary survey made by the United States Department of Agriculture.

In this survey 2000 dietary records, each covering a period of seven days, were collected from 1425 families and 575 institutions in 46 states. Sixteen nationalities and many occupations and incomes were represented, as were also both urban and rural localities.

From a summary of 500 of these family records it appears that last year the average cost of food per man per day was 46 cents, with an average return in food value of 3225 calories, 96 grammes protein, 118 grammes fat, and 405 grammes carbohydrate. These figures are in fairly close accord with the dietary standards ordinarily used in discussing such problems of general nutrition.

A comparison of the foodstuffs purchased by the 500 families with the amounts of the same food purchased by 400 families about twenty years ago shows that the amount of meat in the American diet has decreased about 8 per cent., and the amount of grain products about 11 per cent. People are eating more milk, butter, and cheese than they were two decades ago, for the amount of dairy products consumed has increased about 6 per cent. Four per cent. more vegetables and 8 per cent. more fruit are being eaten now.

Some individual food habits undoubtedly need to be corrected, but, judging by these studies, it seems fair to conclude that the average diet seems to be adequate.

R.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, February 18, 1920.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 18, 1920.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 9.

A report of progress was presented by the Committee on Library.

The standing committees for the year 1920–21 were announced.

Mr. H. W. Fulweiler, on behalf of the Committee on Science and the Arts, described the work of Mr. William Wallace Kemp and Mr. William H. Van Horn, of Baltimore, Md., to whom was awarded the Edward Longstreth Medal of Merit, for their Air and Gas Mixing Apparatus. The President presented the medals and accompanying documents to Mr. Kemp, who thanked the Institute for the honor it had conferred upon him and his associate, Mr. Van Horn.

The President then announced that the meeting would become a joint one with the Philadelphia Section, American Chemical Society, and invited Dr. W. A. Pearson, Chairman, to preside.

Dr. Irving Langmuir, of the Research Laboratory, General Electric Company, Schenectady, N. Y., presented the paper of the evening on "The Structure of Atoms and its Bearing on Chemical Valence." A new theory of atomic structures based upon the theories of Rutherford, Kossel and Lewis was offered. By making certain rather simple assumptions regarding the geometrical arrangement of electrons in atoms it was shown how the general properties of all the elements, including those of the eighth group elements and rare earths, can be explained. By means of this new theory it becomes possible to outline a picture of the mechanism of chemical action and the meaning of chemical valence. It leads to a single simple theory of valence which explains and correlates the various theories that have been used in the past. The subject was illustrated by diagrams, charts and lantern slides.

A rising vote of thanks was extended to the speaker, and the meeting adjourned.

R. B. OWENS,
Secretary.

STANDING COMMITTEES, 1920,

OF THE BOARD.

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Coleman Sellers, Jr.

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(Abstract of Proceedings of the Stated Meeting held Wednesday, February 4, 1920.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 4, 1920.

MR. BENJAMIN FRANKLIN *in the Chair.*

Mr. Charles Penrose was unanimously elected Chairman for the year 1920.

The following report was presented for first reading:

No. 2742: Leeds & Northrup's Recording Devices.

R. B. OWENS,
Secretary.

SECTIONS.

Mining and Metallurgical Section.—A joint meeting of the Section and the Philadelphia Chapter, American Steel Treaters' Society, was held in the Hall of the Institute on Thursday evening, January 29, 1920. Prof. A. E. Outerbridge, Jr., and Mr. D. K. Bullens presided jointly.

Albert Sauveur, B.S., Professor of Metallurgy and Metallography of Harvard University, presented a communication, entitled "Fundamental Principles to be Considered in the Heat Treatment of Steel." The fundamental principles underlying the heat treatment of steel were described and discussed with special reference to the results of recent investigations and to apparent exceptions to the general rules. The influence of the work upon the microstructure and physical properties of steel was also considered, as well as the tests to be applied for its study. The subject was illustrated by charts and lantern slides.

After an interesting discussion by the Chairman and others, a vote of thanks was tendered to the speaker.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

Section of Physics and Chemistry.—A joint meeting of the Section and the Philadelphia Section of the American Chemical Society was held in the Hall of the Institute on Thursday evening, February 5, 1920, at 8 o'clock. Dr. Harry F. Keller, on behalf of The Franklin Institute, and Dr. William A. Pearson, on behalf of the American Chemical Society, presided jointly. The minutes of the meeting of January 15th were approved as read.

Richard B. Moore, Sc.D., Chief Chemist, U. S. Bureau of Mines, Washington, D. C., delivered a lecture on "Helium." The history, physical and chemical properties, and occurrence of this rare element were described. An outline was given of the various processes which have been used on a commercial scale for the extraction of helium in quantity from the natural gas of certain regions in the United States. The use of

helium as a substitute for hydrogen in dirigibles and balloons was discussed. The lecture was illustrated with lantern slides and experiments.

The paper was discussed by Messrs. Miner, Norman, and Henderson. On motion of Dr. Walton Clark, a vote of thanks was extended to Doctor Moore. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 11, 1920.)

RESIDENT.

MR. H. H. PLATT, Mechanical Engineer, 1819 Walnut Street, Philadelphia, Pa.

NON-RESIDENT.

MR. KENNETH R. BROWN, Chemist, Atlas Powder Company, and for mail, Atlas Club, Tamaqua, Pa.

MR. FREDERIC V. HETZEL, Mechanical Engineer, Church and Dean Streets, West Chester, Pa.

MR. A. J. MOORE, Assistant Inspector of Ordnance, U. S. N., Bethlehem Steel Works, and for mail, 511 South 6th Street, Allenown, Pa.

MR. RALPH H. MÜLLER, Student, University of Pennsylvania, and for mail, 2929 North 12th Street, Philadelphia, Pa.

MR. CARL D. PRATT, Chemist, Atlas Powder Company, and for mail, Atlas Club, Tamaqua, Pa.

MR. S. N. VAN TRUMP, Civil Engineer, Chief Engineer, Water Department, Wilmington, Del.

ASSOCIATE.

MR. JOHN C. DA COSTA, 3D, Mechanical Engineer, The Baldwin Locomotive Works, and for mail, 1529 Pine Street, Philadelphia, Pa.

MR. HI NAM HO, Draftsman, Philadelphia Coppersmithing Company, and for mail, 5530 Angora Terrace, Philadelphia, Pa.

CHANGES OF ADDRESS.

MR. WALTER ATLEE, 1209 John Street, Baltimore, Md.

MR. CLAYTON O. BILLOW, 6800 Sheridan Road, Chicago, Ill.

MR. H. C. BOOZ, Berwind-White Coal Mining Company, 1100 Commercial Trust Building, Philadelphia, Pa.

MR. ARTHUR L. COLLINS, 5616 Crowson Street, Germantown, Philadelphia, Pa.

MR. JOHN L. COX, 12 Summit Street, Chestnut Hill, Philadelphia, Pa.

MR. R. E. GILLMOR, Gotham Hotel, 5th Avenue and 55th Street, New York, N. Y.

MR. ROBERT E. HORTON, R. F. D. No. 1, Voorheesville, N. Y.

MR. F. J. LEMAISTRE, 810 Bellevue Court Building, Philadelphia, Pa.

MR. BENJAMIN SMITH LYMAN, 112 Elm Avenue, Cheltenham, Pa.

MR. J. MCGOWAN, JR., 32 N. Front Street, Camden, N. J.

MR. ANGUS K. MILLER, 67 Park Avenue, Saranac Lake, N. Y.
MR. F. W. SUTTON, The Chas. E. Bedaux Co., 4500 Euclid Avenue, Cleveland, Ohio.
MR. JOHN C. TRAUTWINE, 3RD., 1108 S. 46th Street, Philadelphia, Pa.
MR. E. A. UEHLING, 3226 McKinley Boulevard, Milwaukee, Wis.

NECROLOGY.

Hugh McCaffrey was born in Bambridge, Ireland, on June 11, 1843, and died in Philadelphia on December 15, 1919. He came to the United States when a young man and was a pioneer in the manufacture of files in Philadelphia, having established in 1863 the business which bears his name.

Mr. McCaffrey was a member and official of many organizations, and a director of the Beneficial Saving Fund Society. He was greatly interested in the civic affairs of the city of his adoption and at one time acted on an advisory board to one of the Mayors.

Mr. McCaffrey became a member of The Franklin Institute on January 1, 1875.

Mrs. Francis Cabeen, Doylestown, Pa.
Mr. C. J. R. Humphreys, P. O. Box 385, Lawrence, Mass.
Mr. J. Gibson McIlvain, East Downingtown, Pa.
Mr. Edwin F. Smith, 605 Commonwealth Building, Philadelphia, Pa.
Mr. Elwyn Waller, 7 Franklin Place, Morristown, N. J.

LIBRARY NOTES

PURCHASES

ARMSTRONG, E. F.—The Simple Carbohydrates and the Glucosides. 1919.
BACON, J. L.—Forge Practice and Heat Treatment of Steel. 1919.
BROWN, N. C.—Forest Products, Their Manufacture and Use. 1919.
CAREY, A. E., and OLIVER, F. W.—Tidal Lands; a Study of Shore Problems. 1918.
CROSS, ROY.—Handbook of Petroleum and Natural Gas. 1919.
CROWTHER, J. A.—Ions, Electrons, and Ionizing Radiations. 1919.
ELLIS, DAVID.—Iron Bacteria. n. d.
GRAY, ANDREW.—Treatise on Gyrostatics, and Rotational Motion. 1918.
GREENE, J. A.—Treatise on British Mineral Oil. 1919.
MCCLENDON, J. F.—Physical Chemistry of Vital Phenomena. 1917.
MOORE, HAROLD.—Liquid Fuels for Internal Combustion Engines. 1918.
MOSER, ALEXANDER.—Die Elektrolytischen Prozesse der Organischen Chemie. 1910.
OSTWALD, WOLFGANG.—Die Welt der Vernachlassigten Dimensionen. 1919.
ROBSON, A. G.—Engineering Machine Tools and Processes. 1919.
ROSE, E. M.—Diesel Engine Design. 1917.
SMITH, ALEXANDER.—Introduction to Inorganic Chemistry. 1919.
THAYER, G. H.—Concealing-Coloration in the Animal Kingdom. 1918.

GIFTS

Abrasive Company, Catalogue No. 7, and booklet: Abrasive Products for the Foundry. Philadelphia, Pa., 1919. (From the Company.)

American Engineering Company, Catalogue of the Taylor Stoker. Philadelphia, Pa., 1918. (From the Company.)

American Society of Mechanical Engineers, Transactions, vol. xl, 1918. New York, 1919. (From the Society.)

Bacharach Industrial Instrument Company, Catalogue F and Pamphlet P. Pittsburgh, Pa., no date. (From the Company.)

Ball Engine Company, Bulletins Nos. S-16, S-20, S-26, S-30, S-36. Erie, Pa., 1919. (From the Company.)

Bucyrus Company, Bulletins G-91, G-141, C-351, T-1002, G-1751. South Milwaukee, Wis., 1919. (From the Company.)

Canada Department of Mines, Annual Report on the Mineral Production of Canada for 1918. Ottawa, 1919. (From the Department.)

Carrier Engineering Corporation, Booklet, Weather and the Story of How it is Manufactured. New York, 1919. (From the Corporation.)

Dake Engine Company, Catalogue No. 27. Grand Haven, Mich., 1919. (From the Company.)

De Laval Separator Company, Catalogue No. 101. San Francisco, Calif., 1919. (From the Company.)

Delta-Star Electric Company, Bulletin No. 35. Chicago, Ill., 1920. (From the Company.)

Dempsey, W. L., Booklet, The Dempsey Cycle. Philadelphia, Pa., no date. (From W. L. Dempsey.)

Denver Fire Clay Company, Bulletins Nos. 400 and 450. Denver, Colo., no date. (From the Company.)

Duff Manufacturing Company, Bulletin of Duff Jacks. Pittsburgh, Pa., no date. (From the Company.)

Electric Furnace Company, Booklets Nos. 7-B, 8-B, 13-B; and Booklet: Some Types of Baily Electric Furnaces in the Production of War Materials. Alliance, Ohio, no date. (From the Company.)

Electro Dynamic Company, Bulletins Nos. 42, 43, 46, 100, 101, and 200. Bayonne, N. J., no date. (From the Company.)

Esterline Company, Catalogue, Typical Graphic Records. Indianapolis, Ind., no date. (From the Company.)

Florida East Coast Railway Company, Annual Report for 1918. St. Augustine, 1919. (From the Company.)

Franklin Manufacturing Company, Catalogue F. C. 7-19. Franklin, Pa., 1919. (From the Company.)

Fuller Engineering Company, Bulletin No. 21. Allentown, Pa., 1919. (From the Company.)

Hagan Corporation, Catalogue of Boiler Regulation. Pittsburgh, Pa., 1919. (From the Corporation.)

Haiss George Manufacturing Company, Inc., Booklet 619. New York, no date. (From the Company.)

Halcomb Steel Company, Catalogue Describing Crucible and Electric Tool and Alloy Steels. Syracuse, N. Y., 1919. (From the Company.)

V. 19

India Posts and Telegraphs, Annual Report for 1918-1919. Simla, 1919. (From the Director-General.)

Indiana Truck Corporation, Catalogue of Indiana Trucks. Marion, Ind., no date. (From the Corporation.)

Industrial Oil Equipment Company, Bulletin No. 100-L. Philadelphia, Pa., 1919. (From the Company.)

Industrial Works, Book No. 111. Bay City, Mich., no date. (From the Works.)

Interstate Commerce Commission, Thirty-third Annual Report for 1919. Washington. (From the Commission.)

Jones and Lamson Machine Company, Booklet, Advanced Practice in Machine Cam Shafts. Springfield, Vt., 1919. (From the Company.)

Liverpool Literary and Philosophical Society, Proceedings for 1916–1917, 1917–1918. Liverpool. (From the Society.)

Locomotive Stoker Company, Catalogue No. C-2. Pittsburgh, Pa., 1919. (From the Company.)

London Meteorological Committee, Fourteenth Annual Report for the Year Ending March 31, 1919. (From the Committee.)

Maryland Geological Survey, General Report, vol. x, 1918. Baltimore. (From the State Geologist.)

Massachusetts Institute of Technology, Bulletin No. 20. Boston, Mass., 1919. (From the Institute.)

Mount Holyoke College, Catalogue, 1919–1920. South Hadley, Mass., 1920. (From the College.)

Newton Machine Tool Works, Catalogue No. 52. Philadelphia, Pa., 1919. (From the Company.)

New York Public Service Commission, Eleventh Annual Report for the Year 1917. Albany, 1918. (From the Commission.)

New York, Report of the State Engineer and Surveyor for 1908, 1910, 1912, vols. i and ii; 1913, vols. i and ii. Albany. (From the State Engineer.)

New Zealand Department of Mines, Geological Survey Branch, Bulletin No. 22 (New Series). Wellington, 1919. (From the Survey.)

Niagara Machine and Tool Works, Catalogue No. 56. Buffalo, N. Y., no date. (From the Works.)

Pennsylvania Department of Mines, Report, Part 2, 1917. Harrisburg, Pa., 1919. (From the Department.)

Pennsylvania Topographic and Geologic Survey, Report No. xii. Harrisburg, Pa., 1919. (From the Survey.)

Philadelphia Bureau of Surveys, Annual Report for 1918. Philadelphia, Pa., 1919. (From the Bureau.)

R. Accademia delle Scienze dell' Istituto de Bologna, Memorie, Serie vi, Tomo 10; Serie viii, Tomo 1, 2 and 3; Rendiconto, vols. xvii, xviii, xix, and xx. Bologna, Italy, 1918. (From the Secretary.)

Royal Society of New South Wales. Journal and Proceedings, 1918, vol. lii. Sydney, 1919. (From the Society.)

Saint Louis Machine Tool Company, Catalogue No. 16. St. Louis, Mo., 1919. (From the Company.)

Smithsonian Institution, Report of the Secretary for the Year Ending June 30, 1919. Washington. (From the Secretary.)

Stein, John G., and Company, Catalogue of Silica and Fire Brick. Bonnybridge, Scotland, 1919. (From the Company.)

Taylor Instrument Company, General Industrial Catalogue. Rochester, N. Y., 1919. (From the Company.)

Texas Company, Booklet: Wire Rope Lubrication. New York, N. Y., 1919. (From the Company.)

Traveling Engineers' Association, Twenty-seventh Annual Report for 1919. Chicago, Ill. (From the Company.)

Traylor Engineering and Manufacturing Company, Catalogue of Bulldog Gyratory Crushers. Allentown, Pa., 1920. (From the Company.)

Triumph Ice Machine Company, Bulletin 514. Cincinnati, Ohio, no date. (From the Company.)

United States Army, Annual Report of the Chief of Engineers, Parts 1, 2, and 3. Washington, 1919. (From the Office of the Chief of Engineers.)

United States Bureau of Construction and Repair, Annual Report for 1919. Washington. (From the Navy Department.)

United States Bureau of Navigation, Annual Report for 1919. Washington. (From the Navy Department.)

United States Bureau of Yards and Docks, Annual Report of the Chief for 1919. Washington. (From the Navy Department.)

United States Coast and Geodetic Survey, Annual Report for the Year Ending June 30, 1919. Washington, D. C. (From the Survey.)

United States Gypsum Company, Catalogue of Pyrobar Gypsum Tile. Chicago, Ill., 1919. (From the Company.)

United States Navy, Surgeon General, Annual Report for 1919. Washington. (From the Navy Department.)

United States Secretary of the Navy, Annual Report for 1919. Washington, 1919. (From the Navy Department.)

Vaile-Kimes Company, Catalogue S. Dayton, Ohio, 1918. (From the Company.)

Virginia Geological Survey, Bulletin No. xix. Charlottesville, Va., 1919. (From the Survey.)

War Department, Report of the Chief Signal Officer for 1919. Washington. (From the Office of the Chief Signal Officer.)

Western Australia Geological Survey, Bulletins Nos. 77 and 82. Perth, 1919. (From the Survey.)

J. G. White Engineering Corporation, Booklet on Nitrate. New York, no date. (From the Company.)

Wilson Welder and Metals Company, Inc., Catalogue No. 5. New York, 1919. (From the Company.)

Wood Turret Machine Company, Catalogue No. 12. Brazil, Ind., 1920. (From the Company.)

Woodworker Manufacturing Company, Booklet: The Master Woodworker. Detroit, Mich., no date. (From the Company.)

Youngstown Foundry and Machine Company, Catalogue of Rolling Mill and Steel Works Machinery. Youngstown, Ohio, no date. (From the Company.)

BOOK NOTICES.

ELECTRO-ANALYSIS. By Edgar F. Smith, Blanchard Professor of Chemistry, University of Pennsylvania. 6th edition, small 8vo., 339 pages, contents and index. 47 illustrations. Philadelphia, P. Blakiston's Son & Co. $2.50 net.

Doctor Smith has long been known as a pioneer and authority in the field of electro-chemistry applied to analysis, and a comparison of the earliest edition of the present work with that now at hand will show the extraordinary progress that has been made in the field. Of this progress Doctor Smith can truly say, "all of which I have seen and of which a large part I have been." It is indeed astonishing to the chemist who has not kept in touch with the developments in this field of analysis to note the many applications, especially to metals that in earlier days would have been regarded as quite beyond the reach of accurate electrolytic separations, for it was then thought that no metal that acts upon water or that is readily oxidized in the air could be dealt with quantitatively by electrolysis. The present book gives very satisfactory results with alkali and alkali-earth metals. The ingenious application of potential determination, which is now eliminating the use of indicators, is illustrated in the following experiment, quoted in the language of the book. "Further, it was discovered that the separation of these metals (alkali metals) was possible by observing the difference in the decomposition pressures of their chlorides. For example, place a mixture of sodium chloride and potassium chloride in the inner compartment of the double cup (apparatus described and figured). Rotate the anode and close the circuit. As the point of decomposition of potassium chloride is 4/30 volt higher than that of sodium chloride, raise the pressure to 2/30 volt higher than the 'break point' of the mixture and carefully maintain this pressure to the end of the electrolysis. The sodium chloride alone will be decomposed, its chlorine forming silver chloride at the anode, while its sodium will pass into the mercury and form sodium hydroxide with the water in the outer cup. The disappearance of the 'break' of sodium chloride and the substitution for it of the higher decomposition pressure of potassium chloride are the evidences of the completion of the electrolysis." Doctor Smith states that the method is serviceable in the determination of the small amounts of alkali metals which occur in silicates, which will be a great boon to mineralogists and petrologists.

The book contains an extensive bibliography and constitutes a most valuable addition to analytic literature.

HENRY LEFFMANN.

THE PREPARATION OF ORGANIC COMPOUNDS. By E. De Barry Barnett, B.Sc. (Lond.), A. I. C. 2d edition, small 8vo. 226 pages, contents and index. 54 illustrations. Philadelphia, P. Blakiston's Son & Co., 1920. $3.25 net.

In the preface allusion is made to the extent to which the world has been for many years dependent on Germany for the more recondite phases of applied organic chemistry, and the importance of escaping from this

dependency. It is pointed out that a chemist who is specially familiar by actual practice with a limited number of chemical processes is often prefered to a chemist just from college. This is, however, illusory, as the specialist is often merely a superior type of foreman, and cannot bring to the solution of problems wide knowledge that the college-trained man has. Too often knowledge which cannot be at once turned into dividends is apt to be regarded as merely ornamental. A fact that may seem merely academic will often lead to a valuable discovery. With these views of the author all trained scientists will agree. The object of science is the discovery of truth.

Turning to matter of the book, we find that after about thirty pages of description of apparatus, methods and reagents, the description of the preparing of organic bodies begins with the simpler hydrocarbons, then takes up halogen derivatives, and proceeds to alcohols, aldehydes, acids, nitriles, nitroso- and nitro-compounds, amines, azo- and sulpho-compounds, winding up with a large collection of miscellaneous compounds of complex character, including many of the dyes and so-called coal-tar synthetics. The text is clearly written, the nomenclature up to date, the chemical composition and reactions very frequently illustrated by the use of structural formulas, in which the reviewer is pleased to note that the benzene hexagon is correctly used in accordance with Kekulé's suggestion, a rule that is by no means always followed. That the chemist must still depend upon German authorities for information in this field is shown by the numerous references to German periodicals, but English chemists have never "lost their heads" on this subject, having apparently been guided by the old Roman maxim, "Fas est et ab hostis doceri." A book such as the one in hand will go far towards relieving English-speaking nations of dependence on any continental authority, but scientists cannot, it is to be hoped, ever be brought to ignoring any investigation, whether made by enemy or friend, rival or associate.

Lastly it is proper that the printer should be commended for the excellent typographic work and general neatness of the book.

HENRY LEFFMANN.

A TREATISE ON QUALITATIVE ANALYSIS. By Frank Clowes, D.Sc. (Lond.), F.I.C., and J. Bernard Coleman, A.R.C.Sc. (Dublin). 9th edition, 8vo., 386 pages, contents and index. London, J. & A. Churchill, 1920. $5.00 net.

This book has been long before the public, and the fact that it has reached the ninth edition is sufficient evidence of the service it has been to the student of chemistry in the field to which it is specifically devoted. It follows, in the main, the general arrangement and scope of books on qualitative analysis and is divided into four parts. Part one describes the apparatus and methods employed, part two the analytic reactions applicable for the detection of substances, and part three the procedures to be employed for the detection of these substances, with an appendix of the usual analytical tables. The fourth part is devoted to description of the equipment of a working laboratory for students. It must be confessed that in several respects this chapter is sadly out of date. No

mention is made of electrical installation. The improved forms of Bunsen burners so familiar to American chemists do not seem to have met with favor in the authors' laboratory. The table of atomic weights contains data in regard to all the elements that are within the purview of the book, but as a table it is incomplete. Formulas are used profusely, which is of great advantage to the student, but the reviewer doubts if any advantage results from the use of the symbol "Am" for the formula NH_4. It seems also that in connection with arsenic, some account should be given of the modern methods for detecting minute amounts of that element. They are safer and more interesting to the student than the old-fashioned Marsh method. In the description of Reinsch's test, it is recommended to clean the copper slip by means of emery paper or nitric acid, and then immerse it in the suspected solution which has been acidulated with hydrochloric acid. A much safer way is, however, to immerse the clean slip in dilute hydrochloric acid, boil the liquid for a few minutes and then add the suspected solution. Notwithstanding these few points on which animadversion seems to be required, the book is a valuable aid to the student in qualitative analysis.

HENRY LEFFMANN.

A SHORT HANDBOOK OF OIL ANALYSIS. By Augustus H. Gill, S.B., Ph.D. Revised 8th edition, small 8vo, 204 pages and index. Illustrated. Philadelphia, J. B. Lippincott Company. $2.50 net.

A work that has gone through eight editions in a little over a score of years requires no encomiums from the reviewer, for it is evident that it meets well the purposes to which it is devoted. Doctor Gill's book is well known as a handy volume for the commercial analyst and works chemist, who has to deal with oils, fats and waxes, a group of the highest importance in both industrial and physiologic chemistry. The present edition preserves the forms of the earlier ones, except as to few changes made necessary by the progress of science. Among these changes are a description of the MacMichael viscosimeter and a means of reductions of viscosimetrical readings to absolute units or poises. Several minor tests for lubricating oils have been introduced. Special tests, methods of analysis and descriptions of special oils and greases have been revised where necessary, particularly in the case of drying oils, and methods of analysis of edible and hardened oils and fats are also included. The work is a compact, well-printed guide to accurate chemical procedure in a very important field.

HENRY LEFFMANN.

REFRACTORY MATERIALS, THEIR MANUFACTURE AND USES. By Alfred B. Searle. 422 pages, contents and index, 135 illustrations, 8vo. Philadelphia, J. B. Lippincott Company, 1917.

The author says in the preface: "Few people realize that almost every modern industry is dependent on the use of refractory materials. Without them no steel, brass or other technically valuable metals or

alloys could be reduced, no furnaces could be constructed, and the use of gas and electricity as sources of power would be impossible. The wonderful progress that has been made in many other branches of industry in the last three decades would have been impossible in the absence of refractory materials."

It has therefore become necessary to study the composition and qualities of known refractories, to seek new sources of the old materials and also new forms. One of the most interesting developments along the latter line is the discovery of abundant sources of zirconium compounds, from which excellent refractory products are obtained. When the incandescent mantle was invented, all zirconium compounds were rare minerals, but at the present time the supply is abundant, being principally the mineral known as baddleyite—zirconium dioxide—obtained from the Sao Paulo district in Brazil. Pure zirconium dioxide (zirconia) has a very low coefficient of expansion, and hence is not liable to crack when exposed to sudden changes in temperature. It is, however, too porous for crucibles, but the addition of from 1 to 3 per cent. of thoria or of dead-burned magnesite will reduce the porosity considerably, without seriously diminishing the refractory character. It is somewhat astonishing to read in an English book, the preface of which is dated two and a half years after the outbreak of the European war, statements that the manufacture of articles from zirconia is principally in the hands of certain German firms. The following paragraph is also interesting: "It is a curious fact that with raw materials inferior to those commonly found in Great Britain (in reference principally to fire-clays), the Belgian, German and Austrian manufacturers have produced goods which are more accurate in shape, less affected by severe conditions of use, and generally recognized as being of higher quality than those made here. Moreover, foreign manufacturers have been able to state in detail the properties of their goods under certain conditions, and have been willing to guarantee results to an extent which most British manufacturers have found impracticable." It is probable that the conditions are to-day more favorable to the British makers of refractories.

HENRY LEFFMANN.

PENROSE'S ANNUAL. Volume xxii of the Process Year-Book. Edited by William Gamble, F.R.P.S. London, Percy Lund, Humphries & Co. Small 4to, 112 pages, with many illustrations in monotone and color. 1920. Price, 10 shillings 6 pence.

This beautiful volume is, as usual in such cases, the product of joint efforts by many firms engaged in the manufacture of materials and apparatus employed in the methods of photo-engraving now so familiar to the public. The reviewer can do little more than commend the execution of the illustrations and presswork, for the book must be seen to be appreciated. An interesting feature is to compare one of the very early issues with the present one, which will enable us to see the enormous strides that have been made in the art of processing. In the 1896 issue there were very few color pictures, and these were notably inferior to present-

day work, although at that time considered to be excellent. The modern processes of color photography have advanced so far that the best work now available comes close to the quality of the artist.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 46. A Study of Airplane Engine Tests. Preprint from the Fourth Annual Report. 40 pages, diagrams, quarto. Washington, Government Printing Office, 1920.

This report is a study of the results of many tests made upon one engine in the Altitude Laboratory of the Bureau of Standards.

Three major variables are considered; namely, speed, altitude, and power; as well as other variables, such as heat distribution, friction losses, carburetion, etc.

The work shows that power varies approximately with the density of the air, decreasing with altitude. The heat supplied in the fuel should be proportional to the density of the air up to nearly 15,000 feet altitude; above this altitude a richer mixture should be supplied. The thermal efficiency based on brake power is a variable, but when based on the indicated power it is nearly a constant for all speeds and altitudes. The sensible heat in the exhaust varies somewhat, but is closely related to the heat rejected on the theoretical (Otto) cycle. The pounds of fuel per I. H. P. per hour is constant up to nearly 15,000 feet altitude, but increases at the higher altitude as a richer mixture is required. When fuel consumption is based on B. H. P., it steadily rises with decrease of density, owing to the effect of a nearly constant friction loss at a given speed.

Report No. 67, Supplies and Production of Aircraft Woods. Preprint from the Fifth Annual Report. 62 pages, maps, quarto. Washington. Government Printing Office, 1919.

The purpose of this report is to present in brief form such information as is available regarding the supplies of the kinds of wood that have been used or seem likely to become important in the construction of airplanes, and the amount of lumber of each species normally put on the market each year. A general statement is given of the uses to which each kind of wood is or may be put, but no attempt has been made to go into a technical discussion of these various uses.

The information contained in this report has been compiled from a great many sources, including principally published and unpublished reports by various members of the Forest Service. Many of the figures given, particularly those relating to amounts of standing timber, are only crude estimates, but until we have a census of the forest resources of the country we shall have to depend largely on guesswork. The figures on production of lumber are taken from the annual lumber census reports and may be relied upon. Estimates as to the proportions of the total lumber production of different species that may be suitable for the manufacture of aircraft are necessarily very general, and are open to modification as methods of sawing or as airplane specifications change.

It is believed that all the species used to any extent or approved for use in American aircraft are included. However, specifications in all probability will be changed as the industry develops. Consequently, the use of many kinds of woods not now considered suitable may eventually be allowed. Copies of the above reports may be obtained from the Committee.

R.

PUBLICATIONS RECEIVED.

The Preparation of Organic Compounds, by E. De Barry Barnett. 2d edition, 273 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Company, 1920. Price, $3.25.

A Treatise on Qualitative Analysis Adopted for Use in the Laboratories of Colleges and Technical Institutes, by Frank Clowes and J. Bernard Coleman. 9th edition, 400 pages, illustrations, plates, 8vo. London, J. & A. Churchill; Philadelphia, P. Blakiston's Son & Company, 1920. Price, $5.

Penrose's Annual: Volume xxii of The Process Year Book, edited by William Gamble, 1920. 112 pages, many illustrations, color prints, plates, quarto. London, Percy Lund, Humphries & Company. Price, 10 shillings 6 pence net.

Canada, Dominion Experimental Farms: Report for the fiscal year ending March 31, 1919. 196 pages, 8vo. Ottawa, King's Printer, 1920. Price, 15 cents.

Canada Department of Mines: Annual Report on the Mineral Production of Canada During the Calendar Year 1918. 80 pages, 8vo. Production of Coal and Coke in Canada During the Calendar Year 1918, 40 pages, 8vo. The Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and Other Metals in Canada During the Calendar Year 1918. 74 pages, 8vo. Ottawa, King's Printer, 1919.

U. S. Bureau of Mines: Bulletin 162. Removal of the Lighter Hydrocarbons from Petroleum by Continuous Distillation, with Especial Reference to Plants in California, by J. M. Wadsworth. 161 pages, illustrations, plates, diagrams, 8vo. Miners' Circular 26. Miners' Safety and Health Almanac for 1920. Published in coöperation with the U. S. Public Health Service. Compiled by R. C. Williams. 51 pages, illustrations, 8vo. Monthly Statement of Coal Mine Fatalities in the United States, October and November, 1919. Compiled by Albert H. Fay. 2 pamphlets, 8vo. Washington, Government Printing Office, 1919.

Utilization of Fish Waste in Canada.—ALFRED J. CURTIS (*Canadian Chemical Journal*, 1920, iv, 4–5) points out that the Canadian waters produce 685,000 tons of fish annually. The annual loss, including fish unfit for human consumption and loss in dressing and marketing, is estimated as 300,000 tons. This waste could readily be converted into fish meal, fish oil, and fertilizer worth aproximately $10,000,000. Under favorable conditions one ton of waste might yield 540 pounds of fish meal worth $20 and 260 pounds of fish oil worth $30; the cost of manufacture would be $10, leaving a profit of $40.

J. S. H.

CURRENT TOPICS.

Activation of Carbon. (From *Proceedings of the Thirty-ninth General Meeting of the American Electro-Chemical Society*, September 23–26, 1919.)—In the paper presented by N. K. Chaney some very interesting data have been brought forward concerning the conditions under which charcoal acquires and retains its absorptive and adsorptive powers. Investigation into this field was mainly stimulated by the exigencies of the late war, in which, as is well known, charcoal was used as the main ingredient of the gas-mask, but the facts thus brought forth are being rapidly applied to industrial requirements. The development of a specifically activated carbon is not based solely on mere improvements of the well-known forms of charcoal, but represents a new viewpoint as to the general nature of the coal and the conditions of the surface. In addition to the work of Chaney, that of A. B. Lamb has contributed to the elucidation of new data. The National Carbon Company operated in conjunction with the Chemical Warfare Service in perfecting the gas-mask material for the United States Army.

The main results set forth in the present paper are as follows:

Elementary carbon, except diamond and graphite, exhibits one of two forms, "active" or "inactive."

All primary amorphous carbon consists essentially of a stabilized complex of hydrocarbons, adsorbed on a base of active carbon.

The active modification is characterized by a high specific adsorptive capacity for gases. The inactive form exhibits no specific capacity of that type. The two forms also differ in temperature of formation and susceptibility to chemical action. The active modification is formed whenever carbon is deposited at low temperatures, either by chemical or thermal methods, in general below 600° C., the inactive form from similar decompositions at higher temperatures. The active form is rapidly attacked by oxidizing agents, even slow oxidation occurring at room temperature. Hydrocarbons that decompose above 700° C. do not yield active carbon; acetylene that may be cracked at a temperature of 300° C. does yield it. In the ordinary processes of destructive distillation at relatively low temperatures, active carbon is first formed, which, by virtue of its adsorptive capacity, takes up a certain amount of the hydrocarbons in contact with and stabilizes them so that they are retained under conditions of temperature and pressure at which they would otherwise be quickly eliminated. For example, quantities of a hydrocarbon resembling anthracene, the boiling point of which is 360° C., have been iso-

lated from cedar charcoal which had been calcined at 850° C., and chlorine substitutions of hydrocarbons may be obtained in notable quantity by passing chlorine over coconut or other charcoals which have been calcined at similar temperatures. An interesting corollary of these investigations is that anthracite may be regarded as a native primary carbon, since it has been shown to possess an active carbon base saturated with adsorbed hydrocarbons. Bituminous coal and ordinary coke are of the same type.

Primary carbon is essentially an adsorption complex of hydrocarbons, adsorbed by a base of active carbon with or without associated non-adsorbed hydrocarbons.

Secondary carbon is primary carbon partially or completely broken up with formation or introduction of inactive carbon by the high temperature decomposition of its hydrocarbons.

According to the theory, carbon deposited at low temperature and absolutely free from hydrocarbons should be the purest form of active carbon and require no activating process. This was confirmed by preparing carbon at 300° C. by transforming carbon monoxide into carbon and carbon dioxide with the aid of ferric oxide as a catalyst. This carbon proved to be very active.

The discovery of the availability of anthracite and other natural coals and of the possibility of making synthetic primary carbon from pulverized materials by the use of the usual binders saved the country from a critical shortage of materials near the close of the war. The special forms obtained were known as Dorsite (from coconut), Bachite (from anthracite), and Carbonite (from lampblack, powdered coal, or similar material). German carbon was made by impregnating wood with metallic salts, carbonizing and then extracting with acid. This process gives but a small amount of active carbon, but leaves an extremely fine capillary mass. These observations led to the distinction between " capillary capacity " and " specific capacity." The former is distinguished by large capacity at high gas concentrations and by rapid equilibrium between the adsorbent and gas-phase in either direction, the gas being removed as easily as it is adsorbed. " Specific capacity " is characterized by very considerable capacity at low gas concentrations and by an extremely low rate of loss during reversal of the adsorption process.

Through these researches it has been made possible to prepare intelligently such active carbon on the large scale from whatever source may be the cheapest or most desirable. The unique properties of the material both as a catalyst and adsorbent suggest that it will find many applications in the industries.

H. L.

Earth-current Telegraphy. CAPT. L. C. CARUS-WILSON. (*The Royal Engineers' Journal*, January, 1920.)—If an electric current is sent into the earth at one point and leaves it at another, it

travels from one point to the other, not in a straight line, but along a series of curved paths. If the two free ends of two wires attached to a receiving instrument are inserted into the earth at some distance from each other, and not far from the earth current just mentioned, they will have a difference of potential and a current will flow through the receiving instrument. If it is a telephone current which flows through the earth, and if the receiving instrument is a telephone, then in the latter may be heard the message picked up from the earth. To magnify the sensitiveness of the receiver the French introduced the "Low Frequency Amplifier," three valves in cascade, with total magnification of 125, by which telephone conversations could be overheard at a distance of several thousand yards. The Huns captured one of the valves, saw for what it was used, and at once applied it themselves. There ensued a war of wits, each side endeavoring to overhear the messages of the other side and to keep its own messages from being intercepted. By the "Fullerphone" messages could be sent by the Morse code without danger of being picked up.

By picking up current from the earth signal messages were sent from one part of the Allied line to another. The secondary of a "Bower Buzzer" (weight 6 pounds and fifty times as strong as a telephone buzzer) was earthed at both ends. The receiving amplifier was likewise earthed at two points about 200 yards apart. The nature of the soil determined the distance over which signals could be sent. In the muddy soil of Flanders the range was 2000 yards under conditions for which the range on the Somme was doubled. The reason was that in the latter region, which has 6 feet of earth with chalk beneath, the electric currents were confined chiefly to a surface layer.

From August to November, 1918, the Royal Engineers erected 326 standard steel bridges and 213 bridges of heavy timber or salved material in the British sector.

G. F. S.

Destruction of Whales by Depth Bombs. (*La Nature*, December 27, 1919.)—To the eye of an observer in an aircraft a submarine and a whale had very much the same appearance provided both were some distance below the surface of the water. This possibility of confusion resulted disastrously to whales in three cases in the North Sea and in one case west of Ireland. In three cases the wounded animal came to the surface. In the fourth case the crew of the dirigible were so certain of their conclusions that they announced by wireless that they had destroyed a submarine, and the news appeared in print. To their discomfiture the mangled body of a whale came to the surface somewhat later in the presence of a torpedo boat.

G. F. S.

A Continuous Process for Electrolytic Regeneration of Chromic Acid is described by RALPH H. MCKEE and SHOO TZE LEO of Columbia University in the *Journal of Industrial and Engineering Chemistry*, 1920, xii, 16–26. The cell contains a porous diaphragm and lead electrodes. The fresh waste liquor containing chromic salts is fed directly into the bottom of the rectangular cell at one end of the inner or cathode chamber and overflows through an orifice at the other end of the same chamber into the outer or anode chamber, in which the level of the electrolyte is kept slightly lower. The finished product is drawn off at the opposite end of the anode chamber by a siphon or overflow. The best results were obtained when the current density was from 0.5 to 2 ampères per square decimeter of anode surface. The yield was best at room temperature, poorer at both 10° C. and 55° C. A decrease in the size of the cathode for the same anode did not make any appreciable difference. The waste liquor was passed through a sand filter 2 inches deep before entering the cell. Further preliminary treatment was unnecessary; the electric current destroyed all organic compounds present in the liquor. The chromic acid content of the product was up to commercial standard. Approximately 3 kilowatt hours of electric energy were required for each pound of chromic acid regenerated. The saving of sulphuric acid, which is also regenerated in the process without additional cost, amounted to almost as much as the cost of the electric energy required to regenerate the chromic acid. J. S. H.

Power from the Sun. A. A. CAMPBELL SWINTON. (*La Nature*, December 18, 1919.)—The power derivable from the sunlight incident on the earth amounts to about 4,000,000 horsepower per square mile in certain latitudes, or in Great Britain to 1000 horsepower per acre during daylight. The author has little hope for utilizing much of this incident power by the heat engine or by processes of vegetable growth. Solar radiation consists of electro-magnetic waves similar to the waves employed in wireless telegraphy, except that the latter are vastly longer. By thermionic or crystal rectifiers it is possible to get uni-directional currents of electricity from the waves of wireless telegraphy. Mr. Swinton raises the question whether by the use of suitable devices the shorter waves of the solar radiation cannot be made likewise to give rise to electric currents.

G. F. S.

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